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Report 1-9

GALCIT REPORT NO. 9

J.P. Galcit

GUGGENHEIM AERONAUTICS LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

AIR CORPS JET PROPULSION RESEARCH

GALCIT Project No. 1

Report No. 9 Sept 8, 1941

RESULTS OF FLIGHT TESTS OF THE ERCOUPE AIRPLANE WITH AUXILIARY JET PROPULSION SUPPLIED BY SOLID PROPELLANT JET UNITS

8 September 1941

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RESULTS OF FLIGHT TESTS OF THE ERCOUPE AIRPLANE WITH AUXILIARY JET PROPULSION SUPPLIED BY SOLID PROPELLANT JET UNITS

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September 2, 1941

TABLE OF CONTENTS

I INTRODUCTION AND SUMMARY

This report deals with the flight tests of the Ercoupe airplane with and without auxiliary jet propulsion carried out at March Field, California during the period August 6 to August 23, 1941, by the Air Corps Jet Propulsion Research Project at the California Institute of Technology.

Capt. H. A. Boushey, Jr., liason officer for the project, was assigned as pilot by the Air Corps Materiel Division, and personnel for assisting the flight tests were made available by the Commanding Officer at March Field.

The flight tests represent the first practical demonstration of the possibilities of auxiliary jet propulsion in the United States. These possibilities, forseen for a number of years, awaited the solution of engineering problems connected with the development of satisfactory jet devices. The present successful flight tests result essentially from the foresight of Major General H. H. Arnold, who supported the initiation of the Air Corps Jet Propulsion Research Project in 1939 under the sponsorship of the Committee for Air Corps Research of the National Academy of Sciences.

The latter committee formed a sub-committee under the chairmanship of Dr. Th. von Kármán, who has personally directed the activities of the project. The project has been under the supervision of Dr. F. J. Malina. Dr. C. B. Millikan and Dr. H. J. Stewart were concerned with the aerodynamic aspects leading to the flight tests. The flight tests were witnessed by Dr. W. F. Durand, chairman of the N.A.C.A. jet propulsion committee and Lt. C. F. Fischer of the Bureau of Aeronautics, Navy Department.

The authors wish to express their appreciation for the cooperation of all the members of the project, especially to Mr. Fred Miller, research assistant on the solid propellant section, and to Mr. E. S. Forman for his

assistance in carrying out the flight tests and recording the tests by means of colored moving pictures.

Auxiliary thrust was supplied to the Ercoupe by multiple jet units charged with a solid propellant. The application of a solid propellant in the first flight tests does not, at the present stage of development, lead to the conclusion that a jet unit utilizing a liquid propellant is inferior. In fact, experiments completed at the project during the period of the Ercoupe tests indicate that satisfactory operation can be expected of a jet unit burning a liquid propellant. Plans are being initiated for a 1000 lb. thrust installation on an airplane of about 10,000 lb. gross weight.

The justification for the choice of the Ercoupe airplane for the first flight tests can be found in Air Corps Jet Propulsion Research Project Report No. 8 by C. F. Damborg and P. H. Dane[1]. This report also includes a detailed study of the performance and flight characteristics of the Ercoupe and a preliminary design layout of the assembly for installing the jet units.

The flight tests were carried out mainly to furnish information on the following problems:

1. Effect of auxiliary jet propulsion on the shortening of the take-off distance and time, with and without overload; and distance to clear a 50 ft. obstacle without overload.
2. Effect on airplane stability and control.
3. Effect of blast from the jet units on the airplane structure.

In addition to these problems the effect of auxiliary jet propulsion on level speed flight near the ceiling of the airplane was determined and a take-off with jet propulsion alone was accomplished.

In Table I the salient points of the flight tests are summarized.

TABLE I

Item	Froupe Without Jet Thrust	Amount of Jet Thrust Added lb.	New Value of Item	Percent Saving %
Take-Off Distance, Ft.	580	170	300	48.3
Take-Off Time, Sec.	13.1	170	7.5	42.8
Distance to Clear 50 ft. Obstacle, Ft.	950	170	550	42.1
Distance to Take-Off with 285 lb. Overload, Ft.	905	166	438	51.6
Time to Take-Off with 285 lb. Overload, Sec.	18.8	166	9.5	49.4
Maximum Indicated Air Speed at 11,400 ft, M.P.H.	62	171	97	56.5 (% increase)

On the basis of the flight tests the following conclusions can be drawn:

1. The solid propellant jet unit delivering approximately 28 lb. thrust for 12 seconds developed by the project gave satisfactory performance. The thrust force was steady during the period of action and the reliability of the units is attested by the operation of 152 units in succession without failures. The units were used within a period of about three days after the propellant charge had been loaded. Tests are underway to determine the effect of long time storage, and also equipment for the preparation and testing of single units delivering 150 lb. thrust is about completed.
2. The use of twin assemblies caused no difficulties with stability and control. The pilot remarked that the auxiliary jet thrust made the handling of the Froupe easier during the whole take-off run. Control was satisfactory even when one assembly alone was delivering jet thrust. These results are especially significant since the Froupe tests represented a scaled down study of the

effect of auxiliary jet propulsion on aircraft of the type of the B-25.

3. The blast from the jet units had no adverse effect on the airplane structure. The duralumin cover of the wing closest to the jet blast was only slightly raised in temperature at the end of the operating period of the units.
4. The theoretical analysis of Report No. 5[2] by C. B. Millikan and H. J. Stewart was satisfactorily verified so that it can be used to predict the performance to be expected by the use of auxiliary jet propulsion
5. It appears justified to carry out flight tests on an airplane having a gross weight of about 10,000 lb. with an auxiliary jet thrust of the order of 1000 lb. supplied by either solid propellant or liquid propellant jet units.

II DESCRIPTION OF THE ERCOUPE AIRPLANE USED IN THE FLIGHT TESTS

The Ercoupe airplane was made available for the flight tests by the Air Corps Materiel Division. It was flown by Capt. H. A. Boushey, Jr. from Wright Field, Dayton, Ohio to March Field, California.

The Ercoupe is a low wing monoplane with tricycle landing gear and a twin tail as shown in Figure 3. The entire airplane is duralumin clad with the exception of the outer wing panels, which are covered with doped fabric. The fuselage is of monocoque type structure. The normal propulsive unit consists of a 6-ft. propeller driven by a Continental Engine Model A-65-8 rated at 65 Horsepower at 2300 r.p.m. A complete description of the Ercoupe can be found in Report No. 8 (loc. cit.)

For flights with auxiliary jet propulsion provision had to be made on the airplane for attaching the jet units. In choosing the location and design of the attachment assembly the following factors were taken into account:

1. Safety for the pilot and airplane.
2. Effect on airplane weight and balance.
3. Effect on airplane flight characteristics.
4. Structural considerations including ease of installation.
5. Effect of jet blast from the jet units.

Furthermore, calculations showed that in order to simulate performance characteristics desired for heavier aircraft, of the type of the B-25, about 150 lb. thrust should be added by jet propulsion to the thrust available from the propeller of the Ercoupe. A single jet unit available for the flight tests was capable of delivering approximately 28 lb. thrust for 12 seconds.

After considering these factors (cf. Report No. 8, loc. cit.) it was decided to use two assemblies each incorporating three of the jet units. The assembly, which will be described in more detail in Part III, consisted of a track frame and mounting bracket.

The two assemblies were attached below the center section of the wing, one on each side of the fuselage as shown in Figures 4 and 5.

In designing the assemblies no effort was expended to reduce their drag to a minimum since the purpose of the flight tests was to compare the performance, with and without jet thrust, of the airplane resulting from the addition of the assemblies.

Calculations of rudder effectiveness (cf. Report No. 8, loc. cit.) for the case in which three jet units misfired on one side showed that although the rudder area of the normal Ercoupe was sufficient to overcome the resulting yawing moment, the margin was rather small. Therefore, each rudder area was increased by the addition of about one square foot of dural sheet as shown in Figure 6.

III DESCRIPTION OF SOLID PROPELLANT JET UNITS AND ERCOUPE ATTACHMENT ASSEMBLIES.

a. Component parts of a jet unit

The jet units utilized in the Ercoupe tests were developed by the solid propellant section of the Air Corps Jet Propulsion Research Project during the period 1939-1941. Very little information on solid propellant rockets delivering a thrust force for a period greater than about one second was available to assist the development. Consequently, considerable theoretical and experimental research was required to work out nozzle and combustion chamber design, propellant composition, loading technique, and manufacture procedure.

The results of the solid propellant experimental research up to July, 1940 are described in Report No. 3,[3] Parts II, III and IV. An analysis of the characteristics of the ideal solid propellant jet unit is presented in Report No. 4.[4] A detailed report of the experimental research conducted since July 1940 is being prepared, therefore, in the following sections the jet unit used in the Ercoupe tests will be only briefly described.

The Ercoupe jet unit consisted of the following component parts as shown in Figures 7 and 8: combustion chamber, base cap, chamber liner, plaster base increment, chamber flange, guide fins, ignition system, exhaust nozzle, exhaust nozzle gasket, nozzle collar, tension bolts, guide bolts and guide bolt sleeves. The dimensions of the component parts can be found in Figure 9, and a photograph of the assembled unit is shown on the right of Figure 8.

In designing the jet unit for the flight tests planned it was not necessary to reduce the weight of the component parts to a minimum by the use of special materials. For that reason Shelby tubing was used for the combustion chamber and mild steel for all parts except the exhaust nozzle and bolts.

It was found that a combustion chamber could be recharged indefinitely. The exhaust nozzle was made of copper of such dimensions as to avoid serious erosion during one run. Aircraft bolts were used throughout. The tension bolts were designed to fail at a chamber pressure of about 6000 lb./sq. in. in order to protect the combustion chamber from being shattered by excessive pressures.

The ignition system consisted of a nichrome wire placed in contact with an ignition charge. One end of the nichrome wire was grounded and the other attached to a commercial 35 mm. spark plug. The plaster base increment was pressed in place under high pressure to prevent gas leakage to the bottom of the powder charge.

The weight of the component parts is shown in the following breakdown:

Combustion chamber, chamber flange and guide fins . .	6.1 lb.
Base cap	.9
Chamber liner	.3
Plaster base increment	.1
Ignition system	.1
Exhaust nozzle and gasket	1.5
Nozzle collar and guide sleeves	1.2
Tension and guide bolts	.5
Total Weight of Unloaded Unit	10.7 lb.

b. Solid propellant and loading technique.

The propellant charge used in the jet units was a type of amide powder designated as GALCIT 27. The powder was prepared from commercial ingredients in batches of about 25 lb. Each jet unit had a charge capacity of approximately 2 lb.

The 2 lb. charge was loaded into the combustion chamber in 22 increments by a plunger having a nose of conical shape. A loading pressure of 18 tons was applied to the plunger in a hydraulic press. Approximately one hour was required to charge a unit.

The last charge increment was reamed flat and a storage plug inserted. The storage plug was held tightly against the powder charge by the nozzle collar and prevented the charge from cracking as well as protecting it from moisture.

Plans for the flight tests called for eighteen jet units to be delivered to March Field every other day. Since only one hydraulic press was available to the project two shifts were employed to load the units.

The night before the flight tests the storage plugs were removed from the charged units, the ignition charge and ignition system put in place, and the storage plugs replaced.

The jet units were taken to March Field in crates. The number of units required for a given test flight were then removed from the crates and the exhaust nozzle installed in place of the storage plug. The operation for each jet unit required about five minutes. Figure 10 shows an exhaust nozzle being bolted in place at March Field.

c. Ercoupe attachment assembly and ignition system.

Since, at the time plans were initiated for the Ercoupe tests, the jet units still suffered a small percentage of failures from pressure buildup in the combustion chamber it was decided to design the attachment assemblies in such a way that the exhaust nozzle and chamber were free to fly clear of the airplane.

As pointed out in Part II, two identical attachment assemblies, each incorporating three jet units, were constructed. The attachment assembly consisted of a track frame and mounting bracket as shown in Figure 11.

The track frame was of welded steel construction and was provided with tracks which supported the jet units by the guide fins. The jet units were mounted side by side in the track frame and as close together as practical to achieve a compact assembly.

The mounting bracket was constructed of 16 gage steel plate formed into a U-shaped channel. The bracket served a dual function in that it supported the track frame and also provided protection for the pilot and airplane in case an excessive pressure built up in the jet unit caused the combustion chamber to shatter. The track frame was fastened to the mounting bracket by four bolts, two on each side. Additional holes were provided in the bracket for the rear bolts so that the inclination of the axis of the jet units could be varied in a vertical plane. The mounting bracket was riveted to two angle irons by means of which the whole assembly was bolted to reinforcing brackets at the bottom of the wing. In order to protect the wing structure against damage from serious shock transmitted to the mounting bracket from a jet unit "blow" the rivets between the bracket and the angle irons were designed to fail before any part of the wing structure. The term "blow" refers to the failure of a jet unit due to the build up of an excessive pressure in the combustion chamber which causes the exhaust nozzle to fly off.

The thrust developed by the jet unit was transmitted to the track frame through the nozzle collar and the unit was prevented from sliding along the track by cotter pins passing through each fin and track. In case of a "blow" the chamber fins sheared the cotter pins and the chamber was then guided in a straight path by the track. The exhaust nozzle and nozzle collar were kept from flying off sideways in case the tension bolts did not fail together by two sleeves sliding on guide bolts attached to the chamber flange.

The ignition system on the Ercoupe consisted of a 6 volt battery, located on the floor of the cockpit, connecting leads to the jet units, and two switches. The jet units were hooked up in a parallel and the charges were ignited by the pilot's throwing a knife switch and pushing a button switch on the instrument panel. The complete installation assemblies and ignition system are shown in Figure 12.

The weights of the component parts of the Ercoupe installation are shown in the following breakdown:

2 Mounting brackets	39.0 lb.
2 Track frames	18.0
4 Wing reinforcing Brackets	8.0
6 Jet Units (charged)	76.2
1 Battery	47.0
Total Weight of Installation	187.2 lb.

For the tests with jet propulsion alone using twelve jet units, another track frame similar to those described before was attached in each assembly as shown in Figures 12 and 13. In Figure 13 a sheet iron plate extending at 45° to the mounting bracket can be seen. This plate was added to protect the pilot from fragments in case a combustion chamber in the lower bank was shattered.

In Figure 14 the pattern left underneath the wing by condensation of the smoke from six jet units in one assembly can be observed.

d. Characteristics of the Ercoupe jet units.

The characteristics that a solid propellant jet unit should have for super-performance applications have been discussed in Reports No. 3 (loc. cit.) and No. 4 (loc. cit.). Briefly, the jet unit must be capable of delivering a thrust force for a period of time of the order of 10 to 30 seconds, the effective exhaust velocity must be in the neighborhood of 5000 ft. per sec., the rate of burning of the solid propellant from 1 to 1-1/2 in. per sec. at a combustion pressure not exceeding 2000 to 4000 lb. per sq. in. and the thrust coefficient should have a value in excess of 1.2.

The jet unit developed and used in the Ercoupe tests had, on the average, the following specifications:

GALCIT 27

Average thrust = $F_{av.}$ = 27.8 lb.

Effective time = t_{eff} = 11.4 sec.

Effective exhaust velocity = c = 5450 ft./sec.

Rate of burning = r = 1.0 in./sec.

Average chamber pressure = $p_{c_{av.}}$ = 2,100 lb./sq. in.

Thrust coefficient = C_F = 1.5

The thrust-weight ratio of an Ercoupe jet unit was 2.6. The thrust-weight ratio of the complete Ercoupe installation for six jet units was 0.9. The latter thrust-weight ratio is rather low and can be materially improved by the use of units delivering a higher thrust.

During the Ercoupe flight tests a sample of each powder batch was loaded into either an Ercoupe jet unit or into a special testing unit provided with a chamber pressure tap and fired on the project. The variation with time of the thrust of the Ercoupe units and the variation of thrust and chamber pressure of the testing units were recorded photographically. The results of the batch sample tests are plotted in Figures 15 to 36. When either the pressure or thrust were not recorded the results of previous tests were extrapolated to supply the missing data. Extrapolated results are indicated by dashed lines in the figures. In some of the batch sample tests the length of the powder charge was shorter than used in the flight tests and therefore the effective time is also shorter.

A complete record of the batch tests is collected in Table II. In the table the following notation is used:

W_c	= weight of propellant charge, lb.
l_c	= length of propellant charge, in.
d_c	= diameter of propellant charge, in.
d_t	= diameter of exhaust nozzle throat, in.
d_e	= diameter of exhaust nozzle exit section, in.
ϵ	= exhaust nozzle expansion ratio
l	= length of expanding section of the exhaust nozzle, in.
α	= half angle of exhaust nozzle expanding section, degrees
$\frac{f_c}{f_t}$	= ratio of cross sectional area of charge to nozzle throat
ρ_p	= density of propellant charge, slugs/in.^{3}
t_{tot}	= total time pressure or thrust was recorded, sec.
t_{eff}	= time corresponding to period during which average thrust and pressure acted, sec.
p_{c_e}	= equilibrium chamber pressure, lb./sq. in.
$p_{c_{av.}}$	= average chamber pressure, lb./sq. in.
$F_{av.}$	= average thrust delivered by unit, lb.
C_m	= mass flow coefficient
C_F	= $\left(\frac{F}{p_c f_t}\right)_{av.}$ = average thrust coefficient
c	= effective exhaust velocity, ft./sec.
r	= rate of burning of the propellant, in./sec.

A complete record of the propellant charges used in the flight tests is collected in Tables III, IV, V and VI. The same notation is used as in Table II. The thrust and effective time of thrust action of the units used in the flight tests were assumed to be the same as the corresponding batch sample tested at the project.

It will be noted that during the first period of the flight tests a number of jet unit failures occurred. During this time experimentation was being carried out at the project to overcome these failures and after the second day of flight testing no failures occurred in 152 successive charges.

A number of misfires were encountered in the flight tests, caused by faulty electrical contacts and broken ignition wires. The misfires were finally practically eliminated by the use of a testing circuit to check the jet unit ignition system before the unit was installed on the Ercoupe.

IV FLIGHT TEST PROCEDURE AND DESCRIPTION OF TESTS

The flight tests of the Ercoupe were carried out at March Field, California in the early morning before winds could interfere. In all the tests the wind speed measured at the March Field Meteorological Station never exceeded 3 m.p.h. and in most cases the wind direction produced a cross wind on the airplane.

To determine the take-off distance the runway was marked off in 50 ft. intervals and the spot at which the wheels left the surface caught by an observer who also timed the take-off with a stop watch. The take-off distance and time were estimated to be accurate to within $\pm 5\%$.

The weight of the Ercoupe was kept the same for all tests except for the overload tests and the tests with jet propulsion alone.

To determine the distance and time required to clear a 50 ft. obstacle poles supplied by March Field were erected on the sides of the runway and a twine carrying streamers stretched across. The time required to clear the obstacle from the start of the take-off was only roughly determined.

The static thrust delivered by the propeller was measured by means of two spring balances, as shown in Fig. 37. It was found that the propeller delivered an average static thrust of 325 lb. The thrust delivered by the jet units was assumed to correspond to the thrust specifications determined at the project.

The results of the flight tests are tabulated in Tables VII, VIII, and IX. A brief description of the tests follows in chronological order.

<u>August 6</u>

Test No. 1 and 2 - The maximum airspeed and rate of climb at 4528 ft. above sea level were determined from the panel instruments of the Ercoupe without and with the jet installation. The flight characteristics of the airplane with the jet assemblies installed were found to be satisfactory.

Tests No. 3 to 8 - The take-off distance and time were measured without the jet assemblies.

Tests No. 9 to 15 - The take-off distances and time were measured with the jet assemblies installed. Tests 10 to 15 were carried out against a considerable headwind so that the results obtained are not considered reliable. Additional take-offs with the jet assemblies installed were made on a number of occasions during the flight test period.

Test No. 16 - A static test was performed with the propeller running and one jet unit in each assembly operating (cf. Fig. 38). The lower wing surface adjacent to the exhaust nozzles was not noticeable raised in temperature and the jets cleared all portions of the airplane structure.

Test No. 17 - One jet unit was placed in each assembly and ignited after the airplane had started taxing down the runway. (cf. Fig. 39). The pilot noted a slight acceleration when the jet thrust began to act.

Test No. 18 - One jet unit was installed in each of the two assemblies, the airplane flown to 3000 ft. above March Field and the powder charges ignited. Jet unit in right assembly failed, the exhaust nozzle and combustion chamber cleared all parts of airplane. No damage resulted from the "blow." The pilot was able to detect a slight yawing moment from thrust delivered by the jet unit in the left assembly.

Test No. 19 - Four jet units were installed, two in each assembly, and fired with the brakes of the airplane set. Of the two jet units in the right assembly one ran satisfactorily, the other misfired; in the left assembly one misfired, the other failed. The blow of the unit that failed caused the riv-nuts at the rear attachment of the angle irons to pull loose. The exhaust nozzle and combustion chamber cleared all parts of the airplane structure.

August 8

Test No. 20 - Four jet units were installed, two in each assembly, and fired with the brakes of the airplane set. Three units operated satisfactorily, one unit in right assembly failed. The exhaust nozzle rebounded from the runway and struck the fuselage, tearing a 10" hole in the skin and shearing a bulkhead (cf. Fig. 40). The combustion chamber traveled about 100 ft. ahead of the airplane before hitting the ground. The blow was rather violent causing the riv-nuts at the rear attachment of the angle irons to pull loose and the dural wing covering immediately above the exhaust nozzle position to stretch, pulling loose four or five rivets. The pilot deserves credit for his willingness to continue flight test as soon as the airplane was repaired.

August 12

Test No. 21 - The hole torn in the fuselage during the last test was repaired as shown in Fig. 41. Four jets were installed and a taxi run made. All jet units functioned satisfactorily. Pilot commented on noticeable acceleration when the jet units were delivering thrust.

Test No. 22 - Four jet units were installed, the airplane flown to 3000 ft. above March Field and the powder charges ignited. All jet units functioned satisfactorily. The pilot commented on marked acceleration - the indicated air speed increasing from 75 m.p.h. to over 90 m.p.h. during the period the jet units delivered auxiliary thrust. The airplane climbed somewhat during the same period, and control was not noticeably affected.

Test No. 23 - The first take-off with auxiliary jet propulsion is shown in Fig. 42. Four jet units were installed and all performed satisfactorily. The charges were ignited before the brakes were released. Pilot noted marked acceleration during take-off run as compared to take-off with propeller alone, and satisfactory control of the airplane. Speed seemed to increase immediately after clearing the ground and satisfactory control of the airplane was obtained during the air-born portion of the jet units' operation.

August 14

Test No. 24 - Taxi run with six jet units installed. Airplane was started rolling and then the powder charges were ignited. The jet blast ceased after approximately an 850 ft. run. One jet unit in the left assembly misfired. Pilot satisfied in all respects with the operation of the other five units.

Test No. 25 - Take-off with six jet units installed. One jet unit in right assembly misfired. Powder charges were ignited before brakes were released. (cf. Figs. 43 to 48).

Tests No. 26 to 28 - Tests to determine take-off distance and time of the airplane with six dummy jet units installed.

Test No. 29 - Take-off with six jet units installed. One jet unit in right assembly misfired. For other comments see Test No. 25.

August 16

Test No. 30 - Test to determine distance and time required to clear a 50 ft. obstacle with auxiliary jet propulsion. Take-off distance and time also observed. The height cleared at the obstacle was estimated by eye. Six jet units installed. One jet unit in each assembly misfired.

Tests No. 31 to 33 - Tests to determine distance and time required to clear a 50 ft. obstacle with six dummy jet units installed.

Test No. 34 - Same as Test No. 30. Six jet units installed. All performed satisfactorily (cf. Fig. 49).

Test No. 35 - Same as Tests No. 31 to 33.

Test No. 36 - Same as Test No. 34.

August 19

Test No. 37 - Same as Test No. 36.

Test No. 38 - Test to determine take-off distance and time with six dummy jet units installed.

Tests No. 39 to 41 - Tests to determine overload capacity of airplane with six dummy jet units installed. Cpl. R. Hamilton, weighing 135 lbs., was carried as passenger and overload built up to 285 lbs. by the addition of sand bags. Take-off distance and time measured.

Test No. 42 - Test to determine take-off distance and time with 285 lb. overload with six jet units installed. All jet units performed satisfactorily.

Tests No. 43 to 45 - Same as Test No. 42 with six dummy jet units.

Test No. 46 - Same as Test No. 42.

August 21

Test No. 47 - Test to determine take-off distance and time with six loaded jet units installed but not fired.

Test No. 48 - Airplane with six jet units installed climbed to 11,400 ft. above sea level, near the ceiling of the airplane, and the powder charges ignited. Maximum level flight speed increased approximately from 62 to 97 m.p.h. indicated air speed. Pilot found flight characteristics satisfactory.

Tests No. 49 to 51 - Same as Test No. 47 with six dummy jet units installed.

Test No. 52 - Same as Test No. 47.

Test No. 53 - Moving pictures taken at about 2000 ft. of Ercoupe with jet units operating. Photographs taken by Mr. E. S. Forman from airplane piloted by Dr. C. B. Millikan.

Tests No. 54 to 56 - Same as Tests No. 49 to 51.

Test No. 57 - Take-off of Ercoupe with six jet units firing compared with take-off of a Porterfield airplane piloted by Dr. C. B. Millikan (cf. Fig. 50). The Porterfield gross weight had been adjusted to make its take-off distance the same as that of the Ercoupe with six dummy jet units installed but not operating.

Test No. 58 - The Ercoupe was taken off with three jet units operating in only the right assembly to determine rudder effectiveness under the conditions of yawing moment due to the jet units. The pilot reported sufficient rudder control.

August 23

Test No. 59 - Provision was made on the Ercoupe for the installation of twelve jet units for attempts to take off without propeller thrust. The propeller was removed as shown in Fig. 51. In this test all jet units performed satisfactorily. To start the airplane rolling a bank of six jet units was ignited and the second bank ignited about seven seconds later. The airplane was unable to take off before the jet thrust ceased acting (cf. Fig. 52).

Test No. 60 - Same as Test No. 59 except that Ercoupe was pulled by a truck to a speed of about 25 m.p.h. before all jet units were ignited. Of twelve units installed one unit misfired due to gasket leak. The Ercoupe left the ground and reached an altitude of about 20 ft. before the jet thrust ceased to act. Strong diving moment when the jet thrust ceased to act caused a rather rough landing.

Test No. 61 - Test to determine take-off distance and time with six loaded jet units installed but not fired. Attachments for extra bank of six jet units used in Tests No. 60 and 61 not removed so that drag of the airplane was larger than in other take-offs with six jet units installed.

Test No. 62 - Final test used to determine take-off distance and time required with propeller plus six jet units firing. All six units performed satisfactorily. (cf. Test No. 61). The end of the climb after take-off is shown in Fig. 53.

V ANALYSIS OF THE PERFORMANCE OF THE ERCOUPE WITH AND WITHOUT AUXILIARY JET PROPULSION

a. Performance and data for the Ercoupe airplane without auxiliary jet propulsion

The anticipated performance and flight characteristics of the normal Ercoupe airplane, with and without auxiliary jet propulsion, have been discussed by C. F. Damberg and F. H. Dane in Report No. 8 (loc. cit.).

Flight tests to determine the actual performance of the Ercoupe used at March Field are described in the preceeding section. The nominal data and performance for the normal Ercoupe are compared in Table X with the Ercoupe used, without and with jet equipment attached. When the jet equipment was attached six dummy jet units were installed in the assemblies.

TABLE X

	Normal Ercoupe at sea level	Ercoupe tested at March Field 1528 ft. above sea level	Ercoupe with jet equipment attached at March Field 1528 ft. above sea level
Gross weight, W, lb.	1175	1178	1178
Maximum velocity, V_{max}, m.p.h.	111	104 at 4528 ft. above sea level	92 at 4528 ft. above sea level
Maximum B.Hp.	65	--	--
r.p.m. at rated speed	2300	--	--
Propeller diameter, D, ft.	6	6	6
Initial thrust of propeller, C_1, lb.	318	325	325
Wing span, b, ft.	30	30	30
Take-off velocity, V_{TO}, m.p.h. (estimated)	41	--	50
Take-off run, S_o, ft.	350	420	530
Take-off time, t_o, sec.	9.8	12	13.1
Distance to clear 50 ft. obstacle, $S_o + S_o$, ft.	706	--	950
Time to clear 50 ft. obstacle, $t_o + t_c$, sec.	16.8	--	19.0

A study of the data in Table X shows that the Ercoupe used in the flight tests without jet equipment compared with the normal Ercoupe had a take-off distance greater by 20% and a take-off time greater by 22.5 per cent. The addition of the jet equipment increased the take-off distance and time of the Ercoupe used by 38 per cent and 9 per cent respectively. The reason for the latter increases was the drag added to the airplane by the jet equipment as discussed in preceeding sections of this report. In the following performance calculations of the effect of auxiliary jet thrust the Ercoupe with the jet equipment attached will be used as a basis of comparison.

b. Results of theoretical analysis of aircraft assisted by auxiliary jet propulsion

An aerodynamic analysis of take-off and initial climb of aircraft as affected by auxiliary jet propulsion was carried out by C. B. Millikan and H. J. Stewart in Air Corps Jet Propulsion Research Project Report No. 5. The following general relations developed are needed to interpret the results of the Ercoupe flight tests:

Take-off distance, S_0' and time t_0' with auxiliary jet propulsion

The take-off distance is given by

$$S_0' = KS_0 + \frac{W}{2gB} \log \frac{A+F-BV_{KS_0}^2}{A+F-BV_{TO}^2} \qquad (1)$$

where the notations so far undefined are:

K = percent of take-off distance without jet assistance at which jet thrust is added. In the Ercoupe tests the jet thrust was begun before the brakes were released so that K = 0.

g = acceleration due to gravity, ft./sec.^{2}

B = thrust decrement coefficient for the normal airplane which during the take-off run accounts for the decrease in propeller thrust, airplane drag, and the decrease in ground friction due to the lift of the airplane.

A = initial accelerating thrust for the normal airplane.

= $C_1 - \mu W$ = static thrust of propeller - ground friction.

μ = coefficient of friction of runway

F = thrust from jet units, lb.

V_{KS_0} = velocity of airplane at time jet thrust begins to act

= 0 for Ercoupe tests

V_{TO} = take-off velocity of the normal airplane

For the Ercoupe airplane used in the flight tests eq. (1) becomes

$$S_0' = \frac{W}{2gB} \log\left(1 - \frac{B}{A+F} V_{TO}^2\right) \qquad (2)$$

If the dimensionless variables $\alpha = \frac{F}{A}$ and $\lambda^2 = \frac{B}{A} V_{TO}^2$ are introduced, the relative saving in distance brought about by auxiliary jet propulsion can be written in the form

$$\frac{S_0 - S_0'}{S_0} = 1 - \frac{\log\left[1 - \frac{\lambda^2}{1+\alpha}\right]}{\log(1-\lambda^2)} \qquad (3)$$

The take-off time is given by

$$t_0' = \frac{W}{2g\sqrt{(A+F)B}} \log\left[\frac{1+\sqrt{\frac{B}{A+F}}\,V_{TO}}{1-\sqrt{\frac{B}{A+F}}\,V_{TO}}\right] \qquad (4)$$

Climb after take-off with auxiliary jet propulsion

The horizontal distance required to climb to a height h is given by the relation

$$S_c' = \frac{Wh}{A} \frac{1}{1+\alpha-\epsilon\lambda_c^2} \qquad (5)$$

where

$$\lambda_c = \sqrt{\frac{B_c}{A}}\,V_{TO}$$

In this equation B_c differs from the B used for the take-off calculations unless the take-off run is made at the C_L for which the lift equals the weight at V_{TO}. It will be assumed that for the Ercoupe B_c = B so that

$$\lambda = \sqrt{\frac{B}{A}}\,V_{TO}$$

$$\epsilon = 1 + \frac{\Delta D}{A\lambda_c^2} = 1 + \frac{\Delta D}{A\lambda^2}$$

In this equation ΔD corresponds to the drag increment at V_{TO} due to the change from take-off to climbing configuration and to loss of ground effect. Since the configuration of the Froupe does not change during the climb ΔD is due only to loss in ground effect.

Equation (5) can therefore be written in the form

$$S_c' = \frac{Wh}{A} \frac{1}{1+\alpha-\epsilon\lambda^2} \qquad (6)$$

The value of ϵ can be determined from the horizontal distance required to climb to a height h without auxiliary jet propulsion.

The relative saving in horizontal distance achieved through the use of auxiliary jet thrust is given by

$$\frac{S_c - S_c'}{S_c} = \frac{1}{1+\alpha-\epsilon\lambda^2} \qquad (7)$$

The time required to climb to an altitude h is given by the relation

$$t_c' = \frac{Wh}{AV_{TO}} \frac{1}{1+\alpha-\epsilon\lambda^2} \qquad (8)$$

Take-off with overload aided by auxiliary jet propulsion

The take-off run in the overload case with auxiliary jet propulsion is given by

$$S_{o_\omega}' = -\beta \frac{W}{2gB} \log\left(1 - \frac{\beta\lambda^2}{1+\alpha}\right) \qquad (9)$$

where $\beta = \left[\frac{(V_{TO})_\omega}{V_{TO}}\right]^2$ and $(V_{TO})_\omega$ is the take-off velocity of the airplane in the overloaded condition, or $\beta = \frac{W_\omega}{W}$ where W_ω is the gross weight of the airplane with overload.

The relative saving in take-off distance by the use of auxiliary jet propulsion is given by

$$\frac{S_0 - S'_{0\omega}}{S_0} = 1 - \beta \frac{\log\left(1 - \frac{\beta\lambda^2}{1+\alpha}\right)}{\log\left(1 - \lambda^2\right)} \tag{10}$$

e. Analysis of Ercoupe flight tests.

The results of the flight tests are collected in Tables VII, VIII and IX. From the tests with jet equipment attached, without auxiliary jet propulsion, the performance factors A, B, λ, α, ΔD, ϵ, and β, defined in the preceding section can be determined.

$$A = C_1 - \mu W$$

The initial thrust of the propeller C_1 was found to have the value of 325 lb., and assuming that the friction coefficient μ for a hard smooth runway has the value of 0.02 then

$$A = 325 - 0.02 \times 1173 = 302 \text{ lb.}$$

The value of B can be obtained from equation (2) by setting F = 0 and taking V_{TO} = 50 m.p.h. = 73 ft./sec. The take-off velocity V_{TO} was estimated from the air speed indicator reading. Solving equation (2) graphically it is found that

$$B = 0.0415$$

The coefficients λ and α are defined as

$$\lambda = \sqrt{\frac{B}{A}}\, V_{TO} = 0.855$$

$$\alpha = \frac{F}{A} = \frac{F}{302}$$

Effect of auxiliary jet propulsion on
take-off distance and time

The dependence of the take-off distance and time of the Ercoupe on the jet thrust added can be calculated from the following relations

$$S_o' = 440 \log\left(1 - \frac{0.732}{1+\alpha}\right)$$

$$t_o' = \frac{5.15}{\sqrt{1+\alpha}} \log\left[\frac{1+0.855\sqrt{\frac{1}{1+\alpha}}}{1-0.855\sqrt{\frac{1}{1+\alpha}}}\right]$$

In Figures 54 and 55 the variation with α of take-off distance and time respectively is shown together with the experimental results of the flight tests. It is seen that the predicted take-off distance curve falls somewhat lower than the measured points. This difference is believed to be within the experimental error of the data and the variation of pilot take-off technique. The predicted take-off time curve fits the measured points very well.

The greatest reduction in take-off distance, amounting to 53.5%, occurred when α = 0.57. The take-off time for this run was reduced 51.7%.

Effect of auxiliary jet propulsion on climb after take-off

In Figure 56 the results of the tests to determine the distance to clear a 50 ft. obstacle are graphically illustrated. Without auxiliary jet propulsion an average of 950 ft. was required from the starting point to clear a 50 ft. height. In this average, Test No. 31 is neglected as the pilot felt that the test was not representative. The average distance required to clear the height after the wheels left the runway was S_c = 370 ft.

From eq. (5) the value of $(1-\epsilon\lambda_c^2)$ can be evaluated for the case of no auxiliary jet propulsion

$$1-\epsilon\lambda_c^2 = \frac{Wh}{AS_c} = \frac{1178 \times 50}{302 \times 370} = 0.527$$

The saving in horizontal distance during climb achieved through the use of auxiliary jet thrust is given by eq. (7)

$$\frac{S_c - S_c'}{S_c} = \frac{\alpha}{(1-\epsilon\lambda^2)+\alpha} = \frac{\alpha}{.527+\alpha}$$

In flight tests No. 34 and 36 a jet thrust of 169.2 lb. was added. Test No. 37 is not regarded as reliable as the airplane was started 450 ft. away from the obstacle and when the pilot saw he could not clear the obstacle he dove under.

For the two tests $\alpha = 0.560$ and the predicted saving in horizontal distance to climb over the obstacle with auxiliary jet thrust is given therefore

$$\frac{S_c - S_c'}{S_c} = \frac{.560}{.527 + .560} = 0.516$$

and

$$S_c' = S_c(1 - .516) = 370 \times .484 = 179 \text{ ft.}$$

The two flight tests gave an average value of $S_0' = 252$ ft. corresponding to a saving of 31.7%. This saving is 20% lower than the theory predicted. It is believed that this difference could have been materially reduced if several more tests had been made to give the pilot an opportunity to improve his take-off technique.

The total distance to clear the 50 ft. obstacle from the starting point was reduced from 950 ft. to 550 ft. or 42.1% by the addition of 169.2 lb. of jet thrust.

Effect of auxiliary jet propulsion on take-off with overload

To determine the effect of auxiliary jet propulsion on the take-off distance and time with overload the Ercoupe took on a passenger and added sandbags until the pilot felt that safety of the airplane in landing did not permit additional overload. The safe overload was found to be 285 lbs. With this overload tests No. 41, 43, 44 and 45 were made to give an average take-off distance of 905 ft.

The ratio of overloaded weight to normal weight for this case is

$$\beta = \frac{1463}{1178} = 1.24$$

The overload amounted to an increase of 67.5% in useful load.

The take-off distance should then be given by the relation (9) which in this case has the form

$$S'_{o_\omega} = -547 \log\left(1 - \frac{.91}{1+\alpha}\right)$$

To determine the effect of jet thrust on the take-off distance with the 285 lb. overload tests No. 42 and 46 were made and gave an average take-off distance of 438 ft. This corresponds to a 51.6% saving in distance. It may be noted that the take-off distance with overload assisted by an average auxiliary jet thrust of 166 lb. reduced the take-off distance to a value below that required by the Ercoupe without overload.

According to the above relation the take-off distance with jet thrust should have been $S'_{o_\omega} = 483$ ft. The difference from the measured take-off distance amounts to 9.3% and could be brought about by the uncertainty in the take-off velocity, which determines λ.

Effect of auxiliary jet propulsion on the maximum speed

Two flights in which the increase of indicated air speed was observed were made. The first was Test No. 22 made primarily to determine the effect of jet thrust on flight characteristics and the second was Test No. 48 made at 11,400 ft. above sea level near the ceiling of the airplane, mainly to satisfy curiosity.

In Test No. 22 the indicated air speed increased from 75 to 90 m.p.h. during the effective time of 12.7 seconds of 111.5 lb. jet thrust. This corresponds to an increase of 20% in indicated air speed. During this test the airplane climbed somewhat.

In Test No. 48 the indicated air speed increased from 62 to 97 m.p.h. during the effective time of 10.3 seconds of 170.6 lb. jet thrust. This amounted to 56.5% increase in indicated air speed.

These results of increased indicated air speed are of doubtful accuracy as there was no way of being assured that the flight path during the action of the jet thrust was horizontal.

Effect of 85 lb. jet thrust in one assembly on the Ercoupe take-off

In Test No. 58, to simulate the misfiring of all jet units in one assembly, the pilot took off the Ercoupe with three jet units in the right assembly delivering 85 lb. thrust for an effective time of 10.9 seconds. The pilot reported satisfactory control during the take-off run and in the climb after take-off.

Take-off of the Ercoupe solely with jet propulsion

In Test No. 60 the airplane was successfully taken-off with jet propulsion alone after an initial roll had been imparted to the craft. This test was made mainly from the viewpoint of curiosity.

Comment on the problem of comparing experimental results with theory

There are two factors that make it difficult to evaluate the theoretical analysis of Report No. 5 (loc. cit.) by comparison of the predicted Ercoupe results with those obtained experimentally. The first difficulty arises from the fact that the actual take-off speeds were not measured. For the analysis of the data it was assumed that the take-off speed was 50 m.p.h. From the theoretical analysis it can be seen that errors in the estimation of the take-off velocity can be quite important. The take-off distance in the overloaded condition is particularly sensitive to errors of this type. It is recommended that for future tests, in particular with larger airplanes, the take-off be recorded photographically by a moving picture camera using a pendulum and grid in order to establish more closely the take-off conditions.

The second difficulty arose in the tests involving a climb after take-off. For these tests, a 50 ft. obstacle was erected and the amount by which the airplane cleared the obstacle was estimated visually, a very inaccurate procedure. The above mentioned photographic technique would eliminate this difficulty also.

References

1. Damberg, C. F. and Dane, P. H., Performance and Flight Characteristics Analysis of the YO-55 (Ercoupe) Airplane with Auxiliary Jet Propulsion and Design Study of Jet Motor Installation. Air Corps Jet Propulsion Research Project Report No. 8, June 7, 1941.

2. Millikan, C. B. and Stewart, H. J., Aerodynamic Analysis of Take-off and Initial Climb as Affected by Auxiliary Jet Propulsion, Air Corps Jet Propulsion Research Project, Report No. 5, January 14, 1941.

3. Malina, F. J., Parsons, J. W., and Forman, E. S., Final Report for 1939-1940, Air Corps Jet Propulsion Research Project, Report No. 3, June 15, 1940.

4. von Kármán, Th. and Malina, F. J., Characteristics of the Ideal Solid Propellant Rocket Motor, Air Corps Jet Propulsion Research Project, Report No. 4, December 1, 1940.

Fig. 1 -- Flight test crew consisted of (left to right) F. S. Miller, J. W. Parsons, E. S. Forman, Dr. F. J. Malina, Capt. H. A. Boushey Jr., Pvt. Kobe, Cpl. R. Hamilton.

Fig. 2 -- Dr. Th. von Kármán, in center, discusses take-off with jet thrust alone.

Fig. 3 -- Capt. H. A. Boushey Jr. shown with Ercoupe airplane used in flight tests.

Fig. 4 -- Front view of Ercoupe showing attachment assemblies installed.

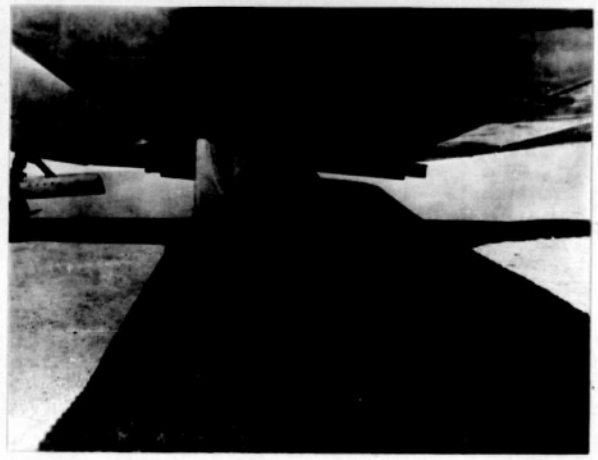


Fig. 5 -- Close up showing side view of jet unit assembly installed on Ercoupe.

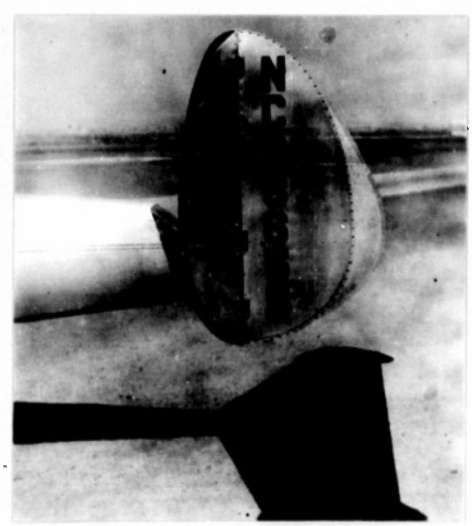


Fig. 6 -- Side view of Ercoupe rudder showing dural sheet riveted to the trailing edge.

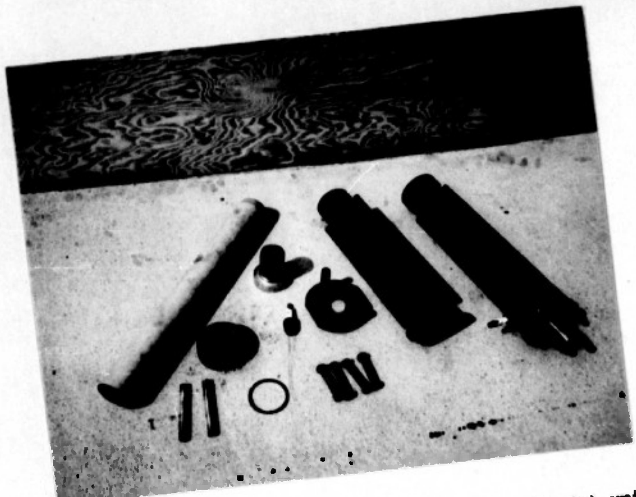
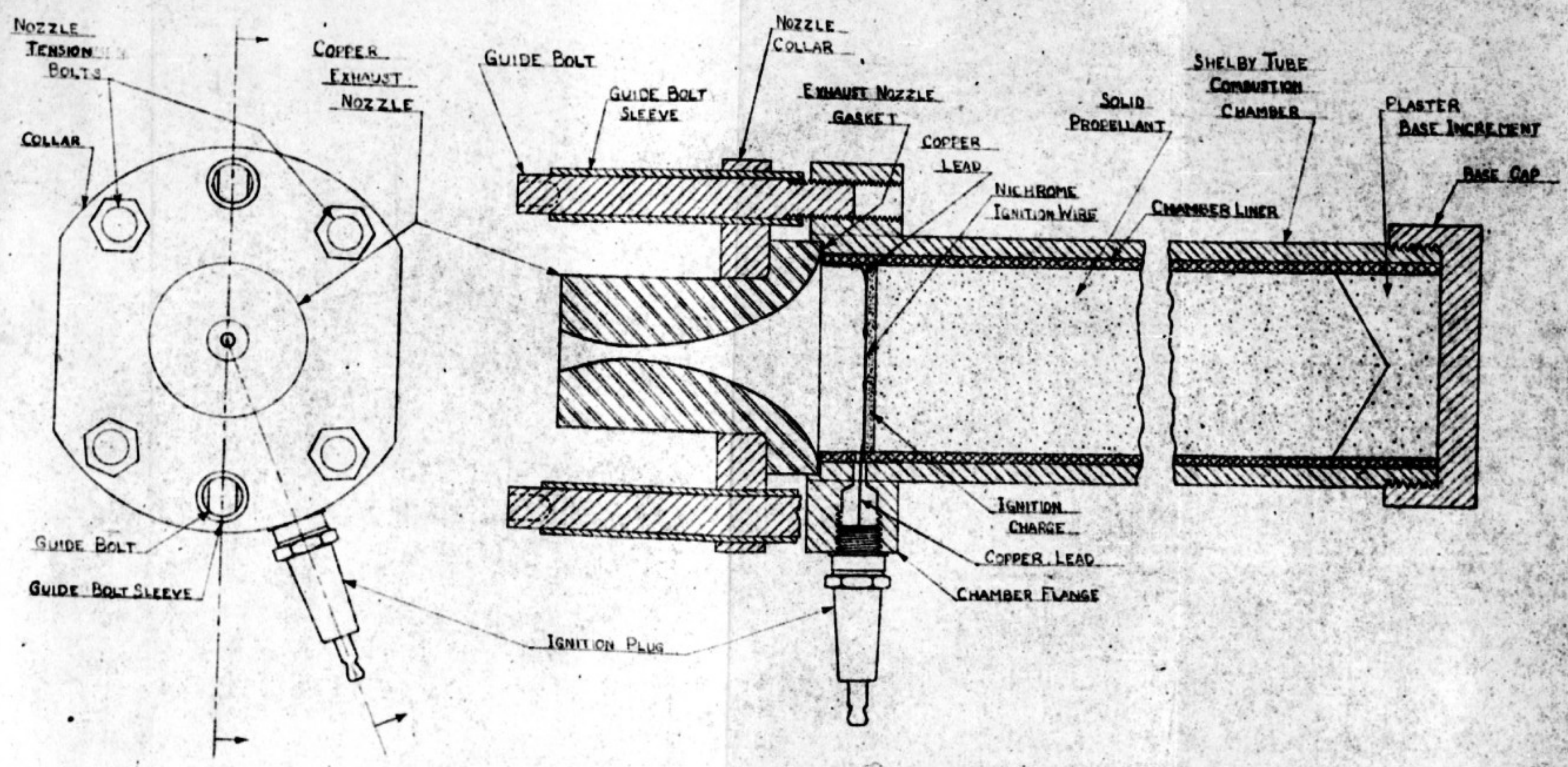


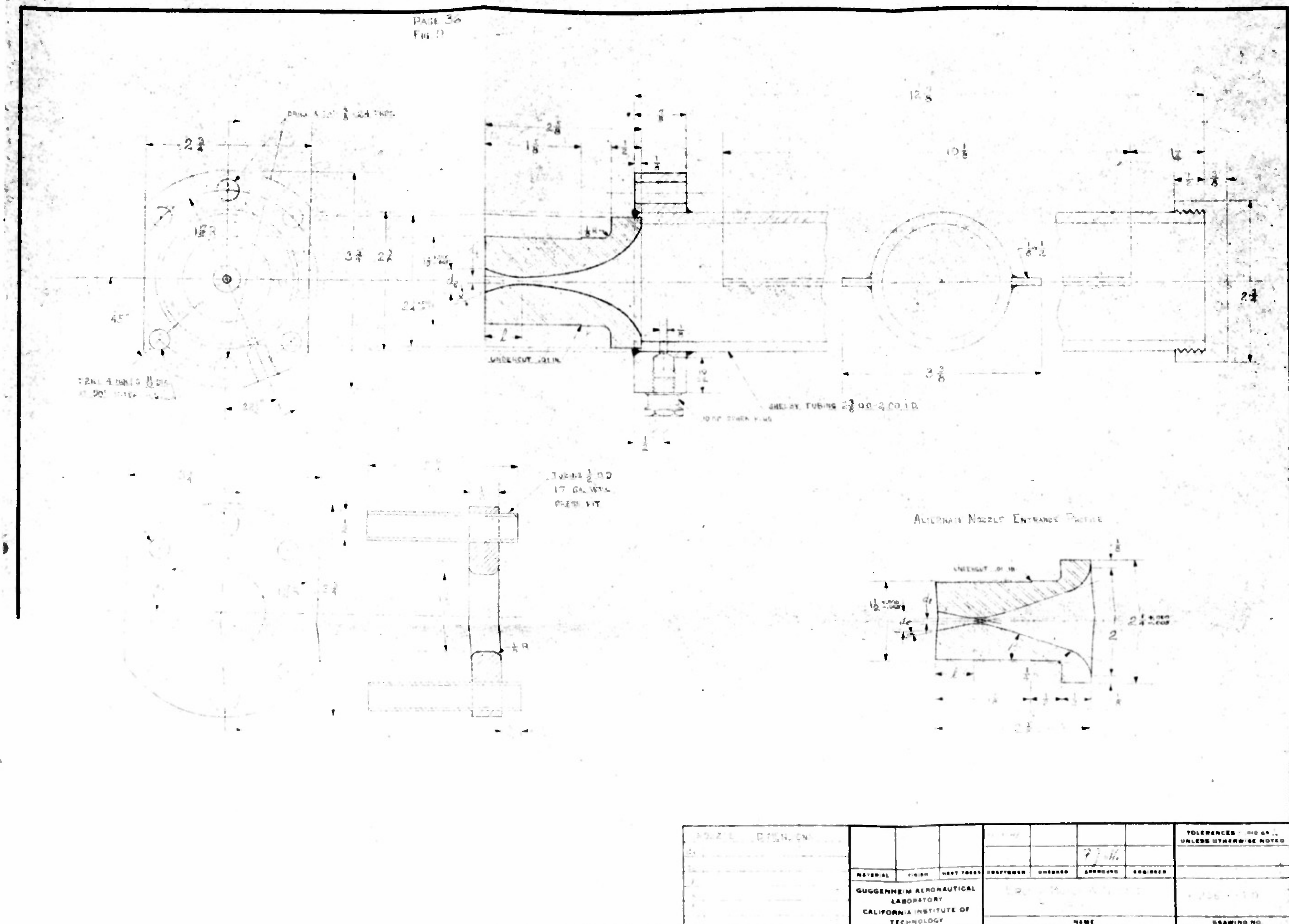
Fig. 8 -- View of component parts of the Ercoupe jet unit.

Fig. 10 -- Final assembly of jet unit at March Field.

FIG 7



			8-27-41				TOLERANCES ± .010 OR 1/64 UNLESS OTHERWISE NOTED
			ANSPACH				
MATERIAL	FINISH	HEAT TREAT	DRAFTSMAN	CHECKED	APPROVED	ENGINEER	
GUGGENHEIM AERONAUTICAL LABORATORY CALIFORNIA INSTITUTE OF TECHNOLOGY			DIAGRAM OF ERCOUPE JET UNIT				2-256-P-115
			NAME				DRAWING-NO.



ALTERNATE NOZZLE ENTRANCE PROFILE
UNDERCUT .01 IN.
SHELBY TUBING $2\frac{3}{8}$ O.D. - 2.00 I.D.
TUBING $\frac{1}{2}$ O.D.
17 GA. WALL
PRESS FIT
TOLERENCES
UNLESS OTHERWISE NOTED
MATERIAL
FINISH
HEAT TREAT
DRAFTSMAN
CHECKED
APPROVED
ENGINEER
GUGGENHEIM AERONAUTICAL LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
NAME
DRAWING NO.

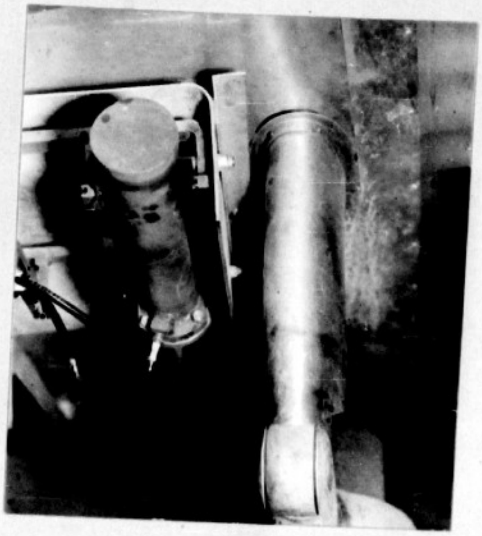


Fig. 11 -- Close up of attachment assembly with one jet unit installed.

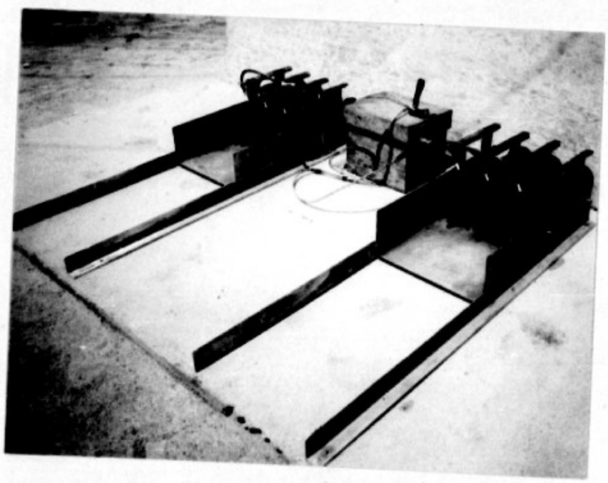
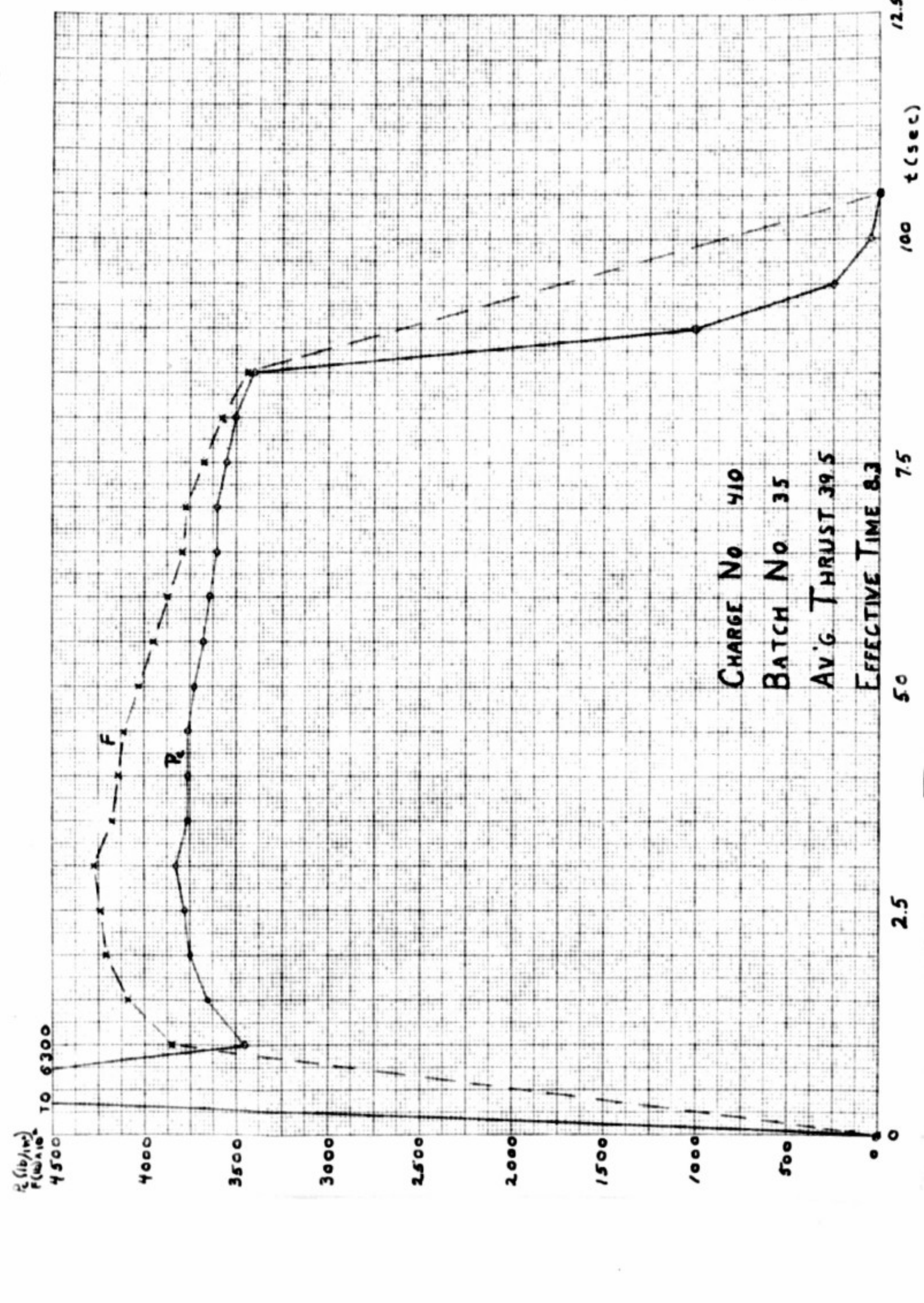


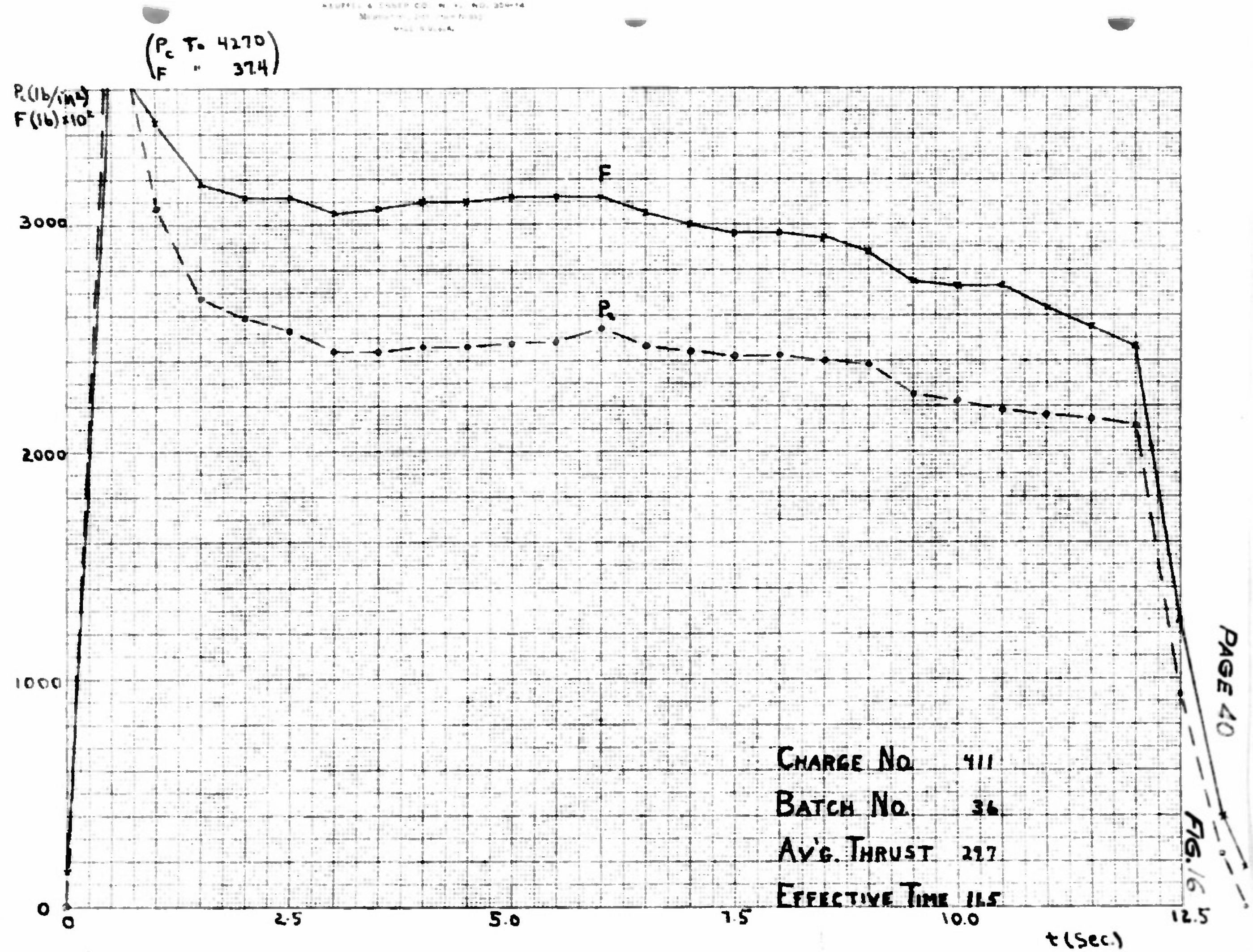
Fig. 12 -- View of Ercoupe jet unit attachment assemblies and ignition system. Extra tracks for six additional jet units are shown.

Fig. 13 -- Rear view of six jet units in attachment assembly before take-off with jet propulsion alone.

Fig. 14 -- Pattern left under wing by condensation of smoke from six jet units in one assembly after take-off with jet propulsion alone.

PAGE 39 FIG. 15

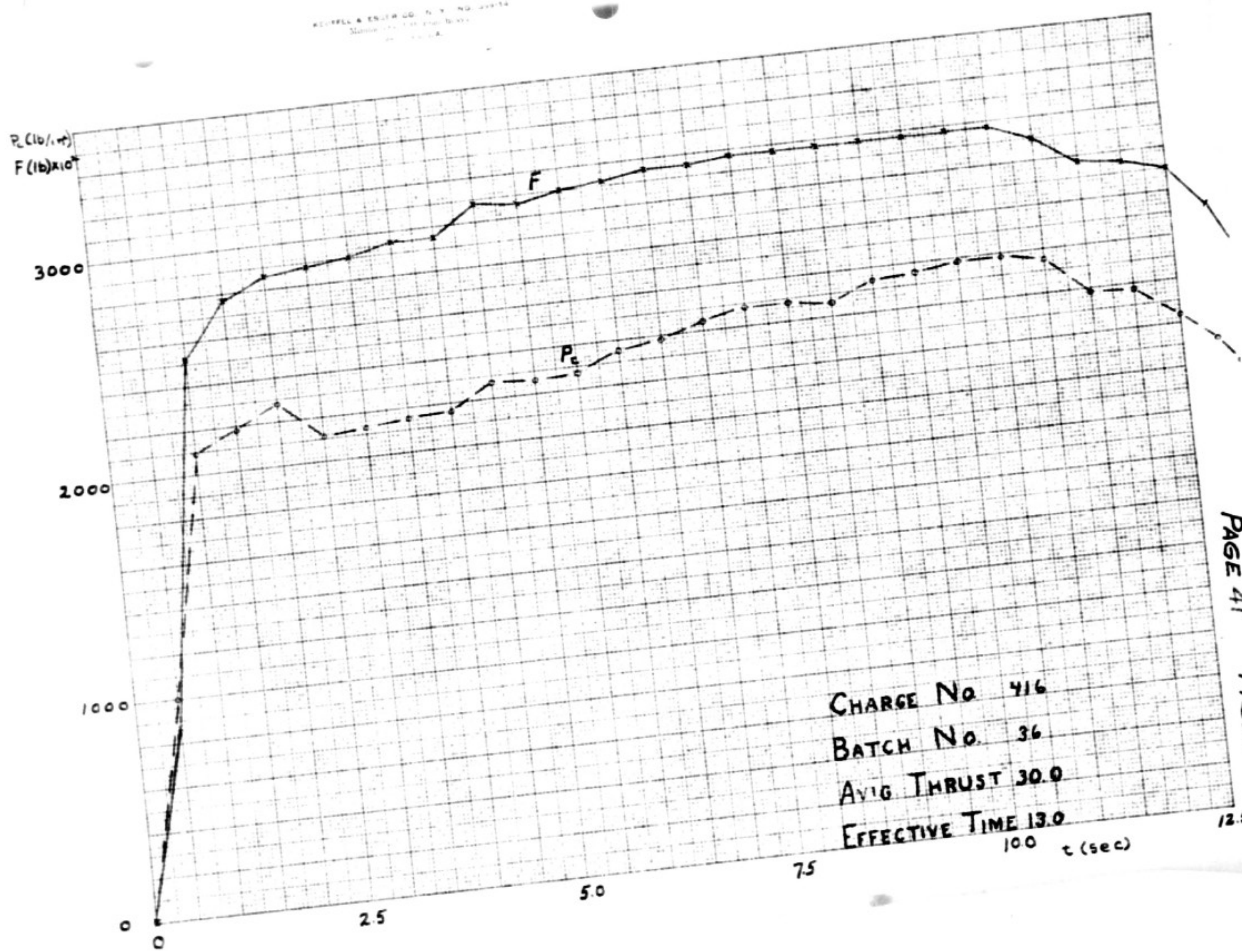




(Pc T. 4270
F " 37.4)
Pc (lb/in²)
F (lb) x10²
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5
t (Sec.)
F
Pc
CHARGE NO. 411
BATCH NO. 36
AV'G. THRUST 297
EFFECTIVE TIME 11.5

FIG. 16

FIG. 17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F (lb)x10⁴
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2000
1000
0
0
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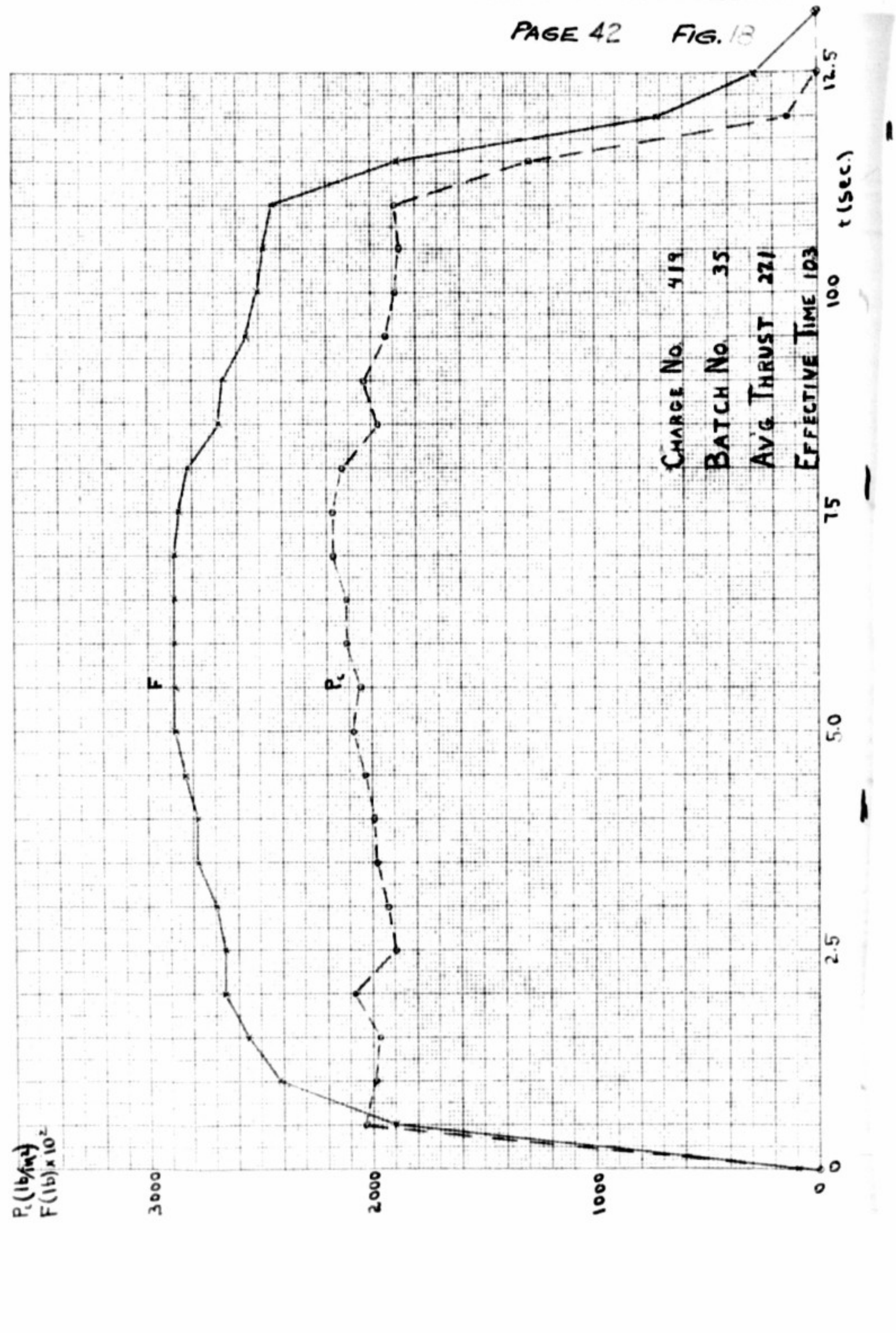
5.0
7.5
10.0
12.5
t (sec)
F
P_c
CHARGE No 416
BATCH No. 36
AV'G THRUST 30.0
EFFECTIVE TIME 13.0

FIG. 18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F (lb) x 10²
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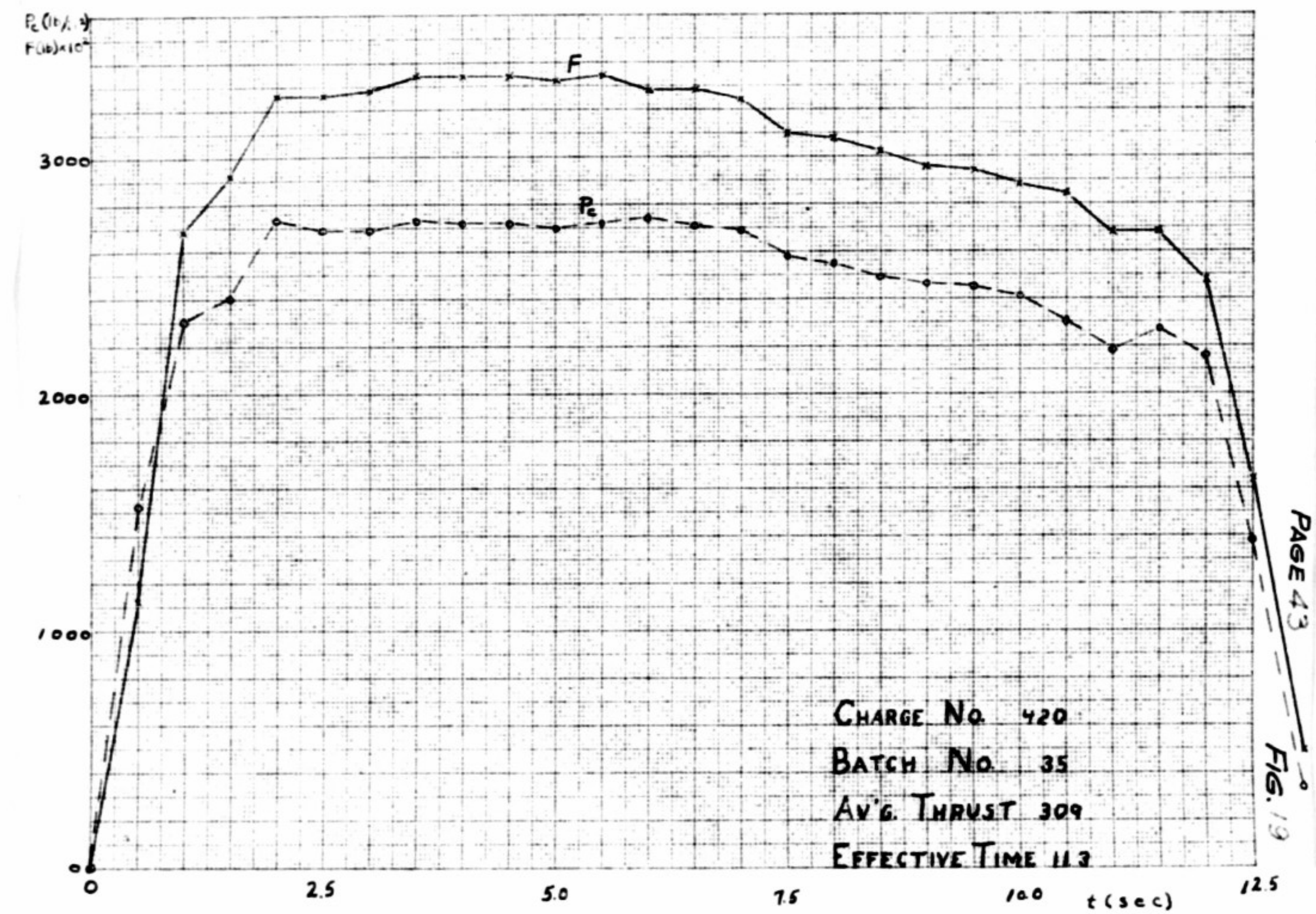
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5
t (sec.)
F
P_c
CHARGE No. 419
BATCH No. 35
AVG THRUST 221
EFFECTIVE TIME 103



PAGE 43

FIG. 19

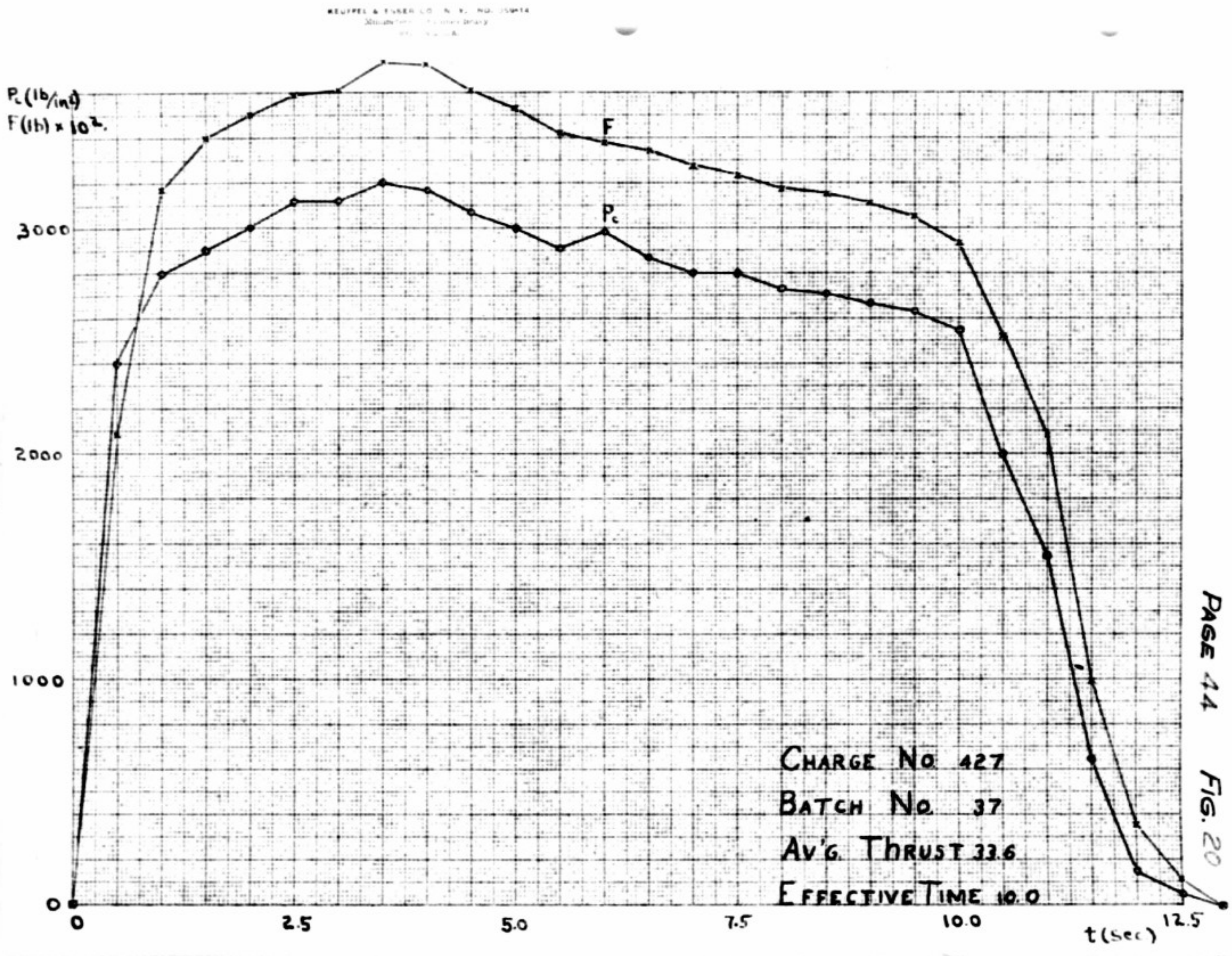

P_c (lb/in²)
F (lb) × 10².
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5
t (sec)
F
P_c
CHARGE NO 427
BATCH NO 37
AV'G. THRUST 33.6
EFFECTIVE TIME 10.0

FIG. 20

FIG. 21

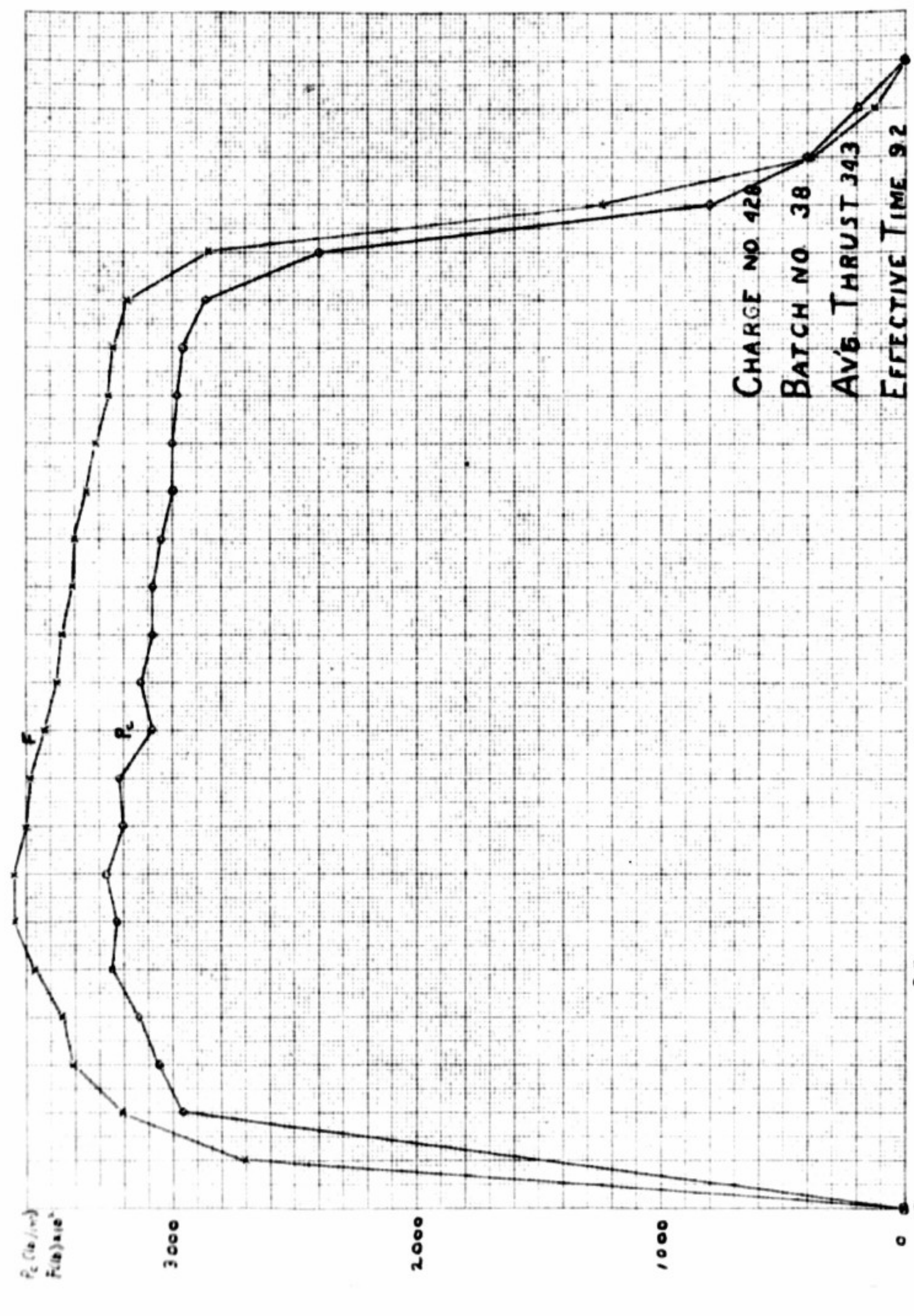
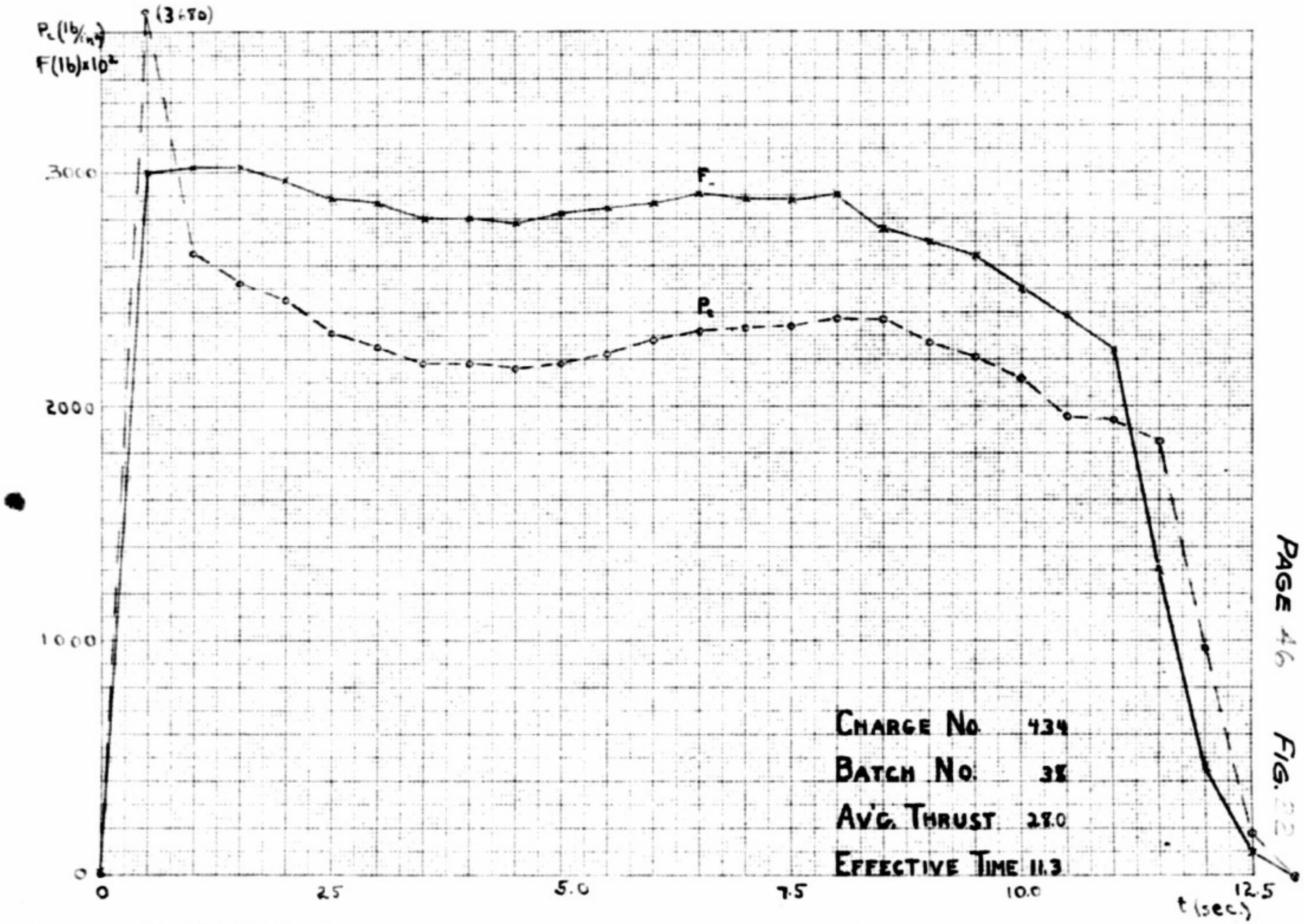
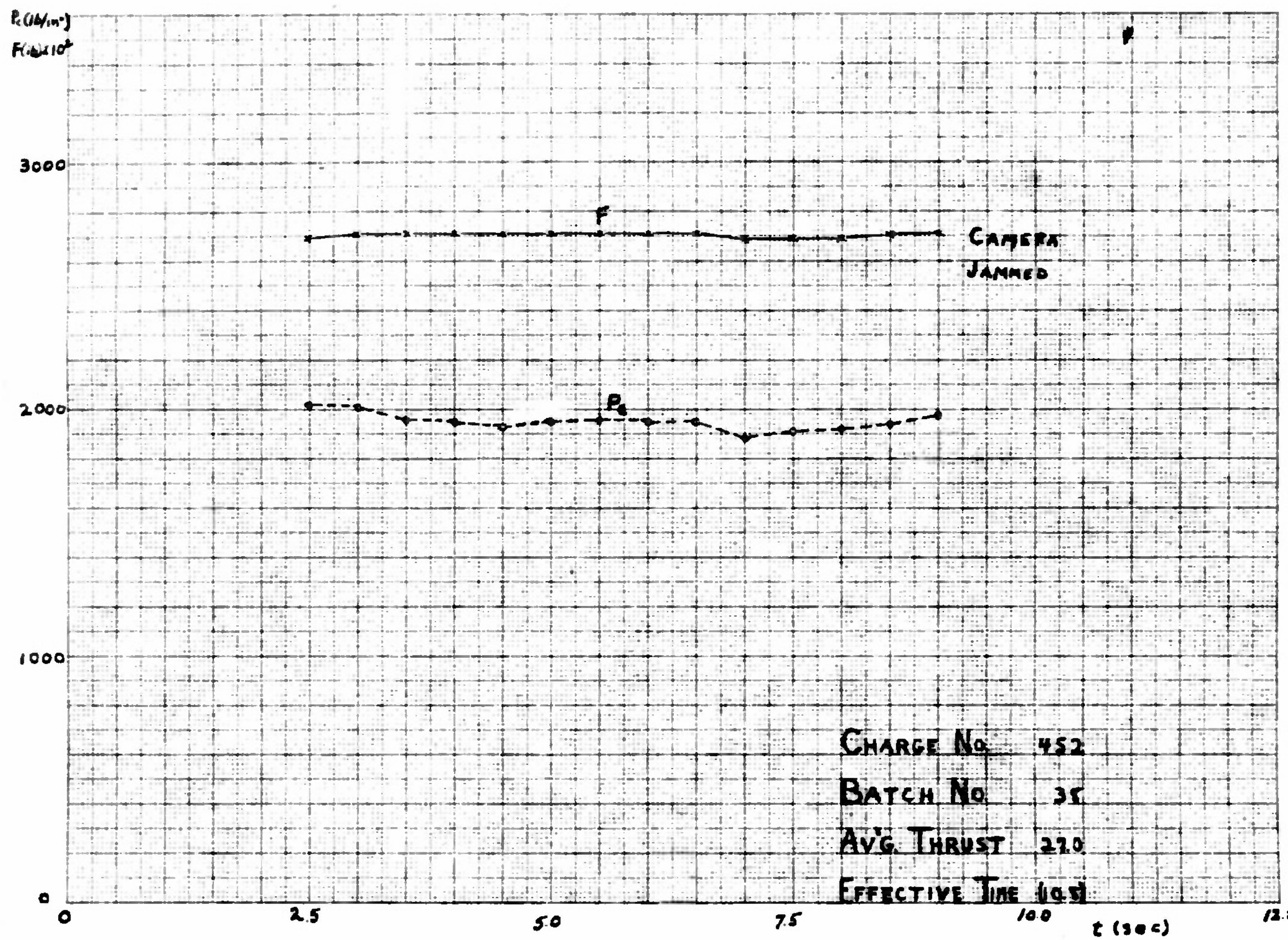

CHARGE NO 428
BATCH NO 38
AVG THRUST 343
EFFECTIVE TIME 9.2
t (sec)
F
P_c
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5

FIG. 22


P_c (lb/in²)
F (lb) x 10²
(3480)
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5
t (sec.)
F
P_c
CHARGE NO. 434
BATCH NO. 38
AV'G. THRUST 28.0
EFFECTIVE TIME 11.3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0
2.5
5.0
7.5
10.0
12.5
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P_c
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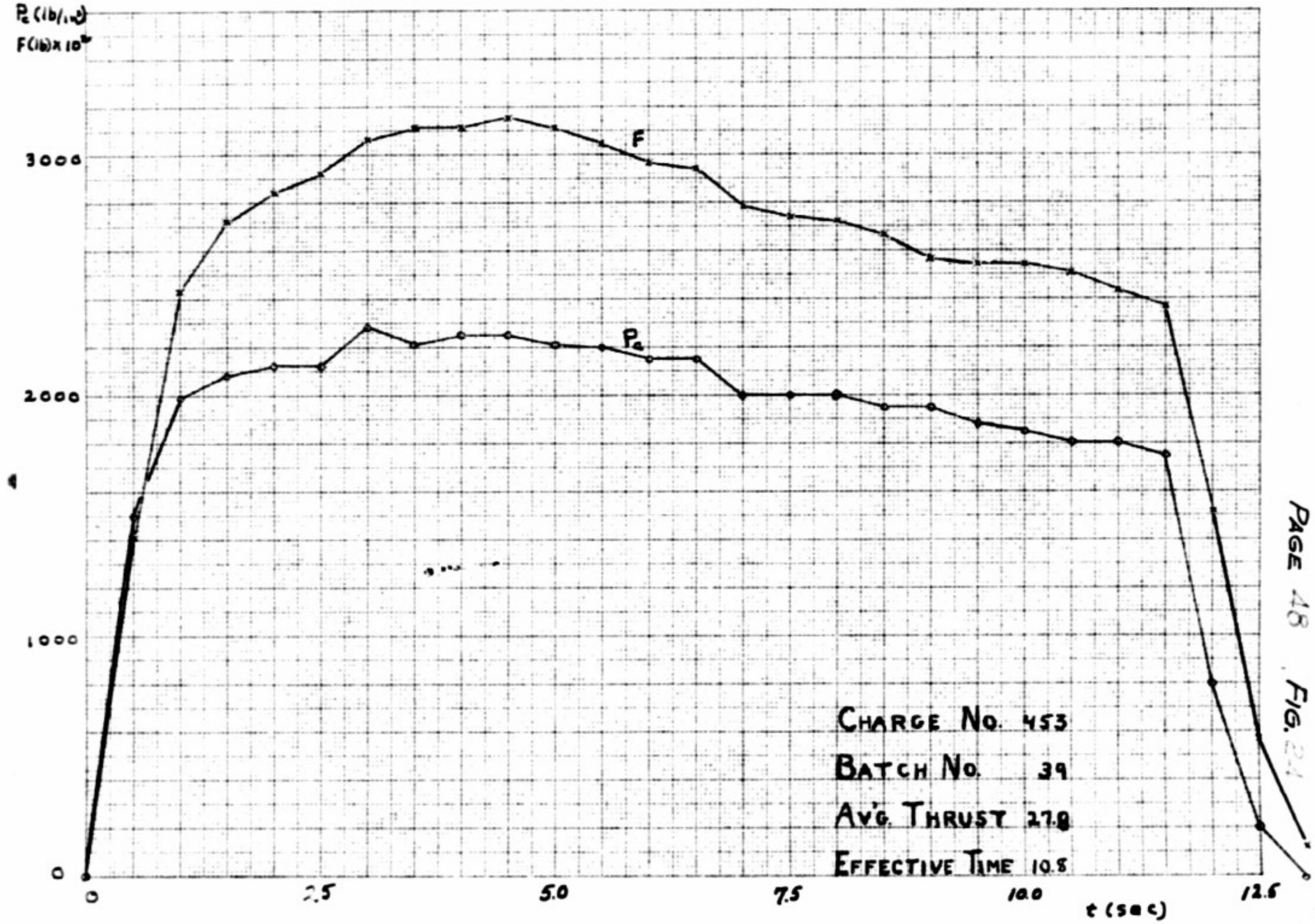
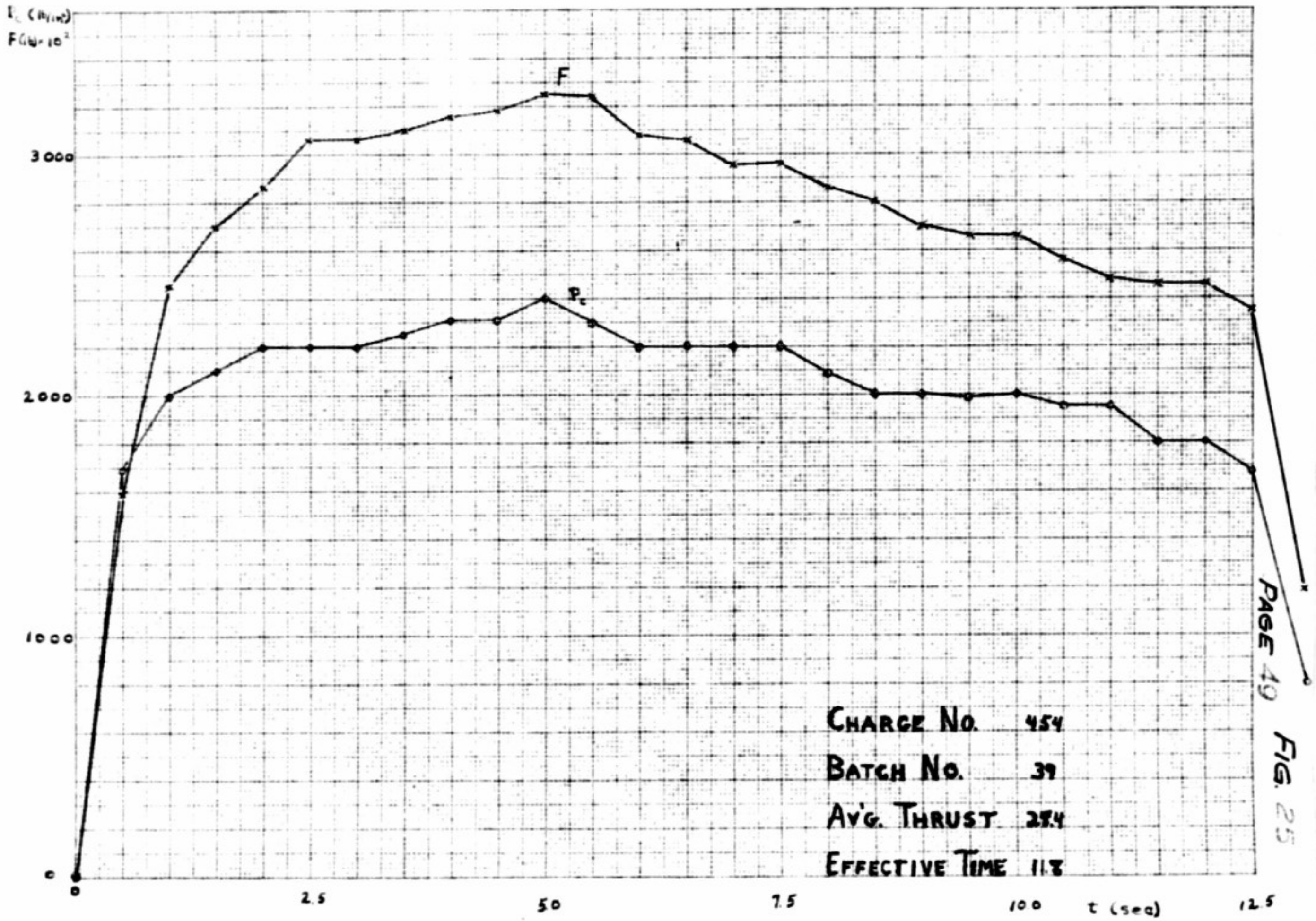
Batch No. 35
Avg. Thrust 220
Effective Time 10.5

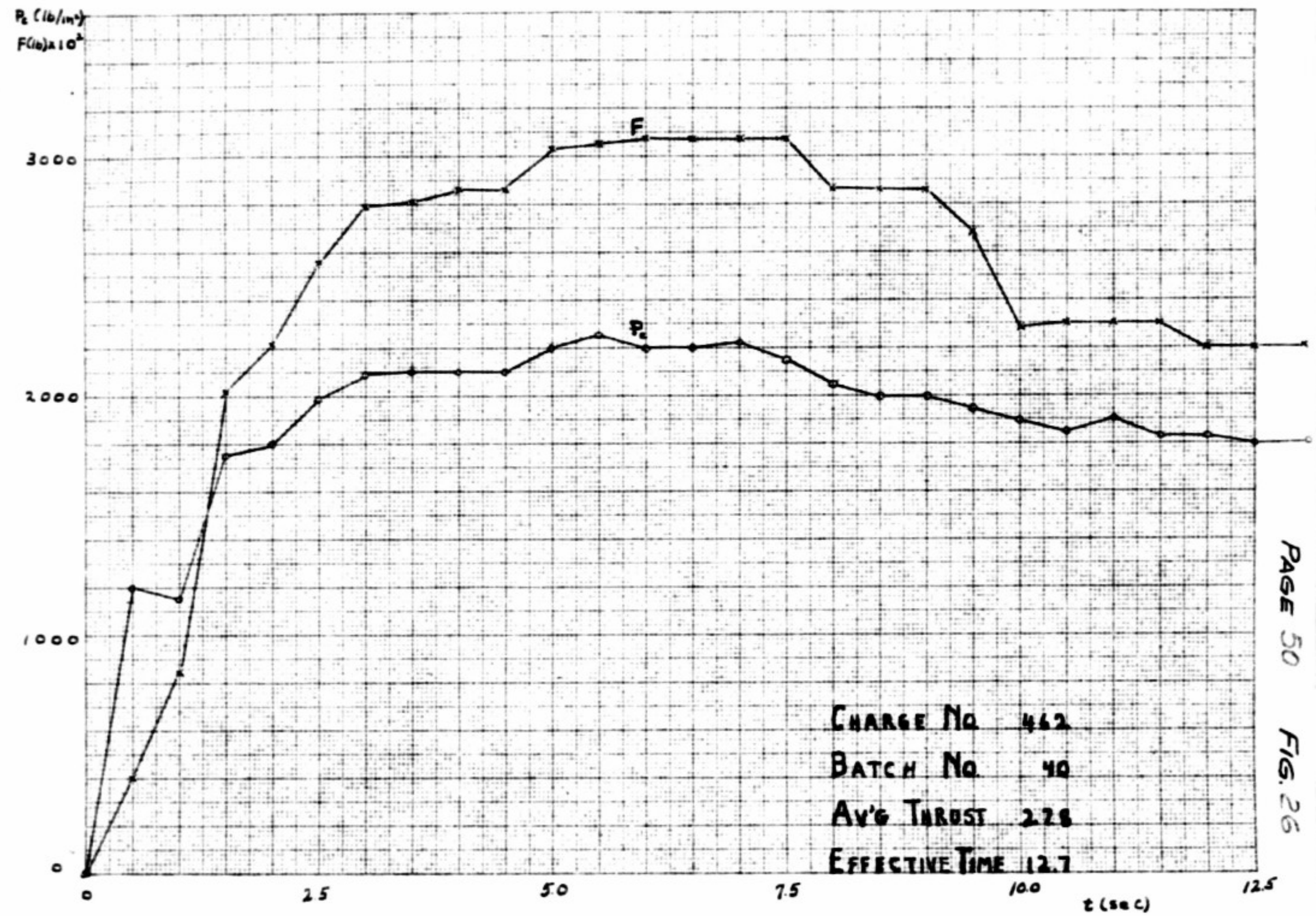
Fig. 23



PAGE 48 , FIG. 24



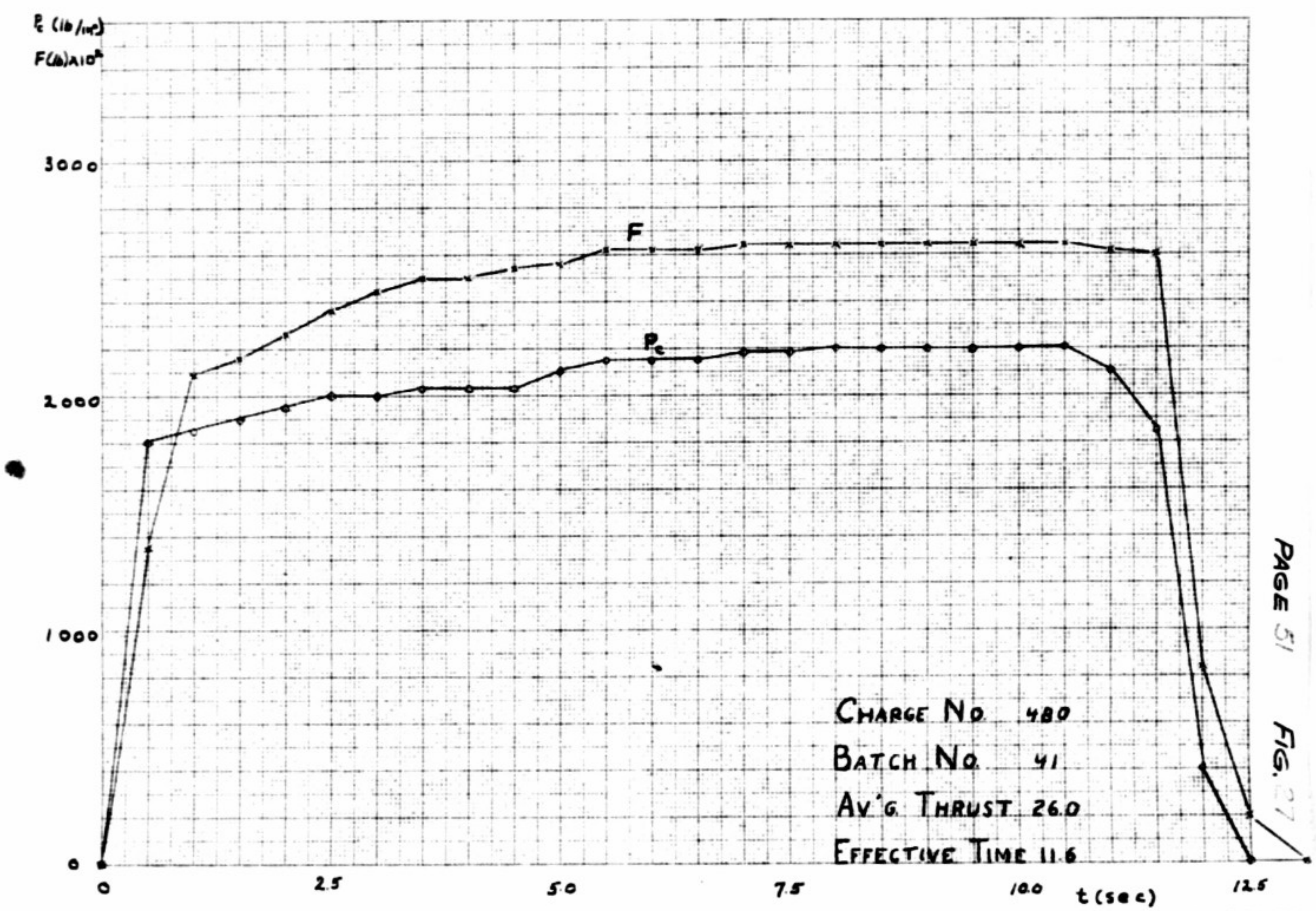
PAGE 49 FIG. 25

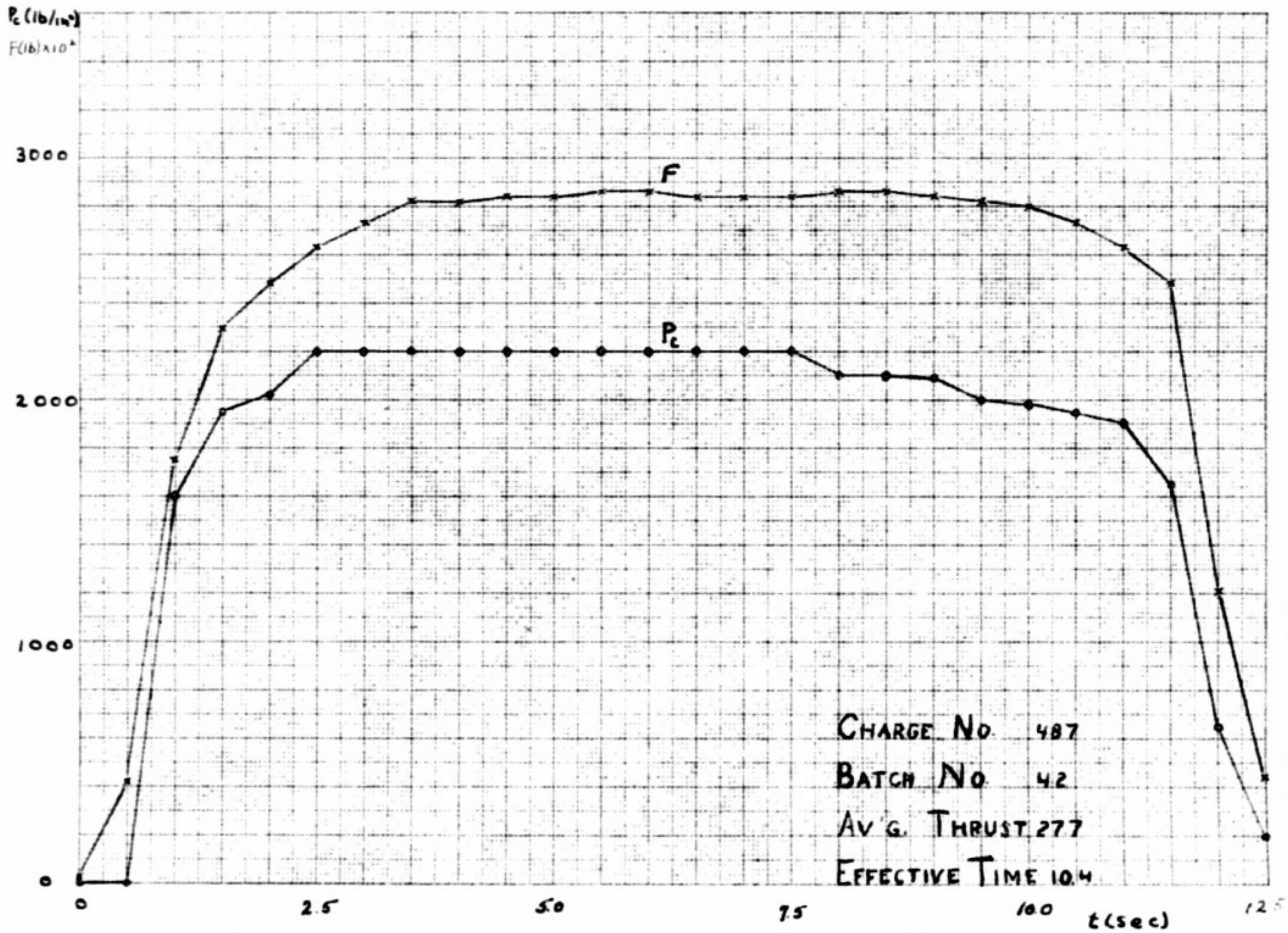


P_c (lb/in²)
F(lb) x 10²
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5
t (sec)
F
P_c
CHARGE NO 462
BATCH NO 40
AV'G THRUST 228
EFFECTIVE TIME 12.7

FIG. 26

PAGE 51 FIG. 27




P_c (lb/in²)
F(lb)x10⁻¹
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2000
1000
0
0
2.5
5.0
7.5
10.0
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t(sec)
F
P_c
CHARGE No 487
BATCH No 42
AV'G. THRUST 277
EFFECTIVE TIME 10.4

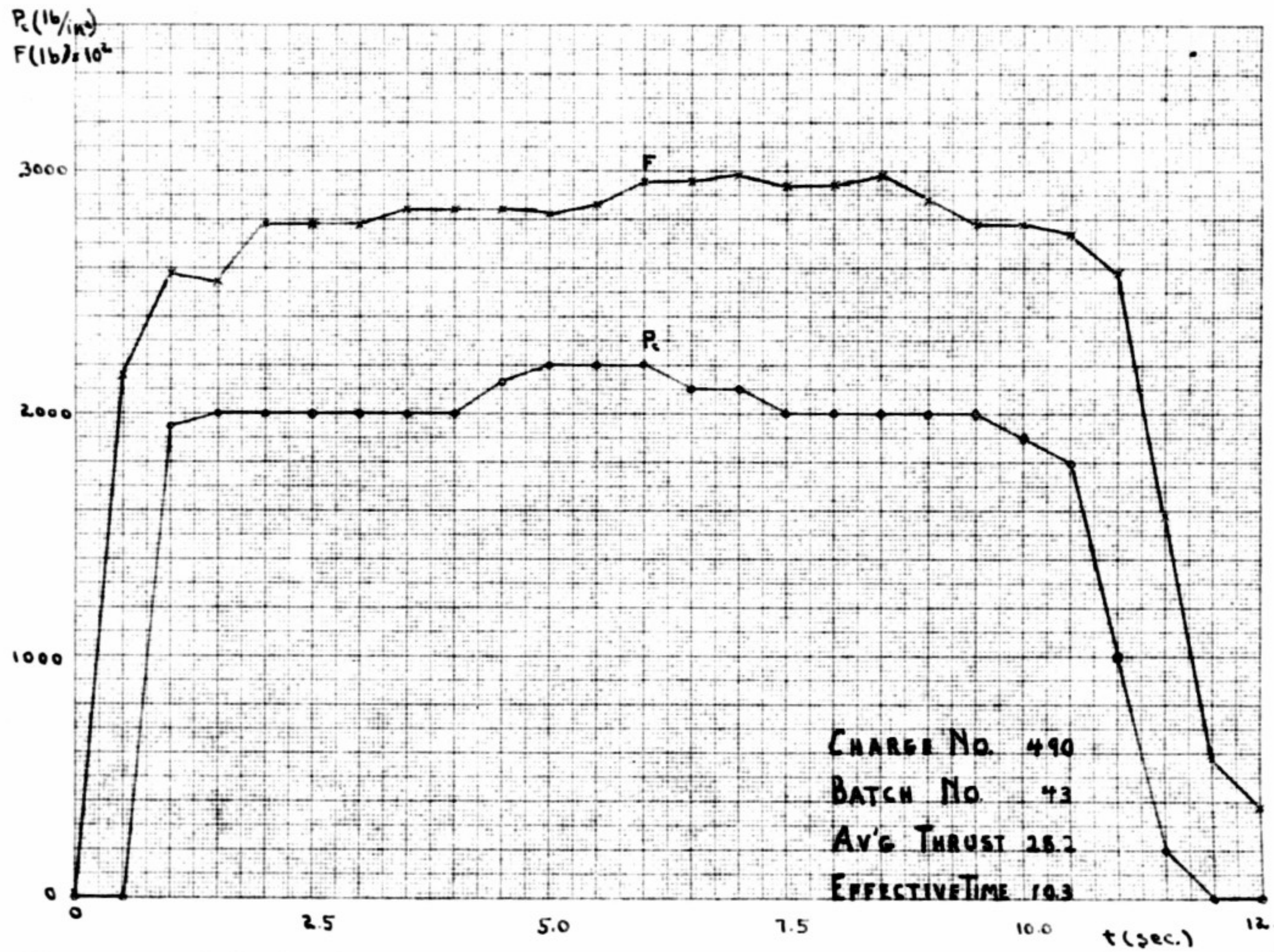
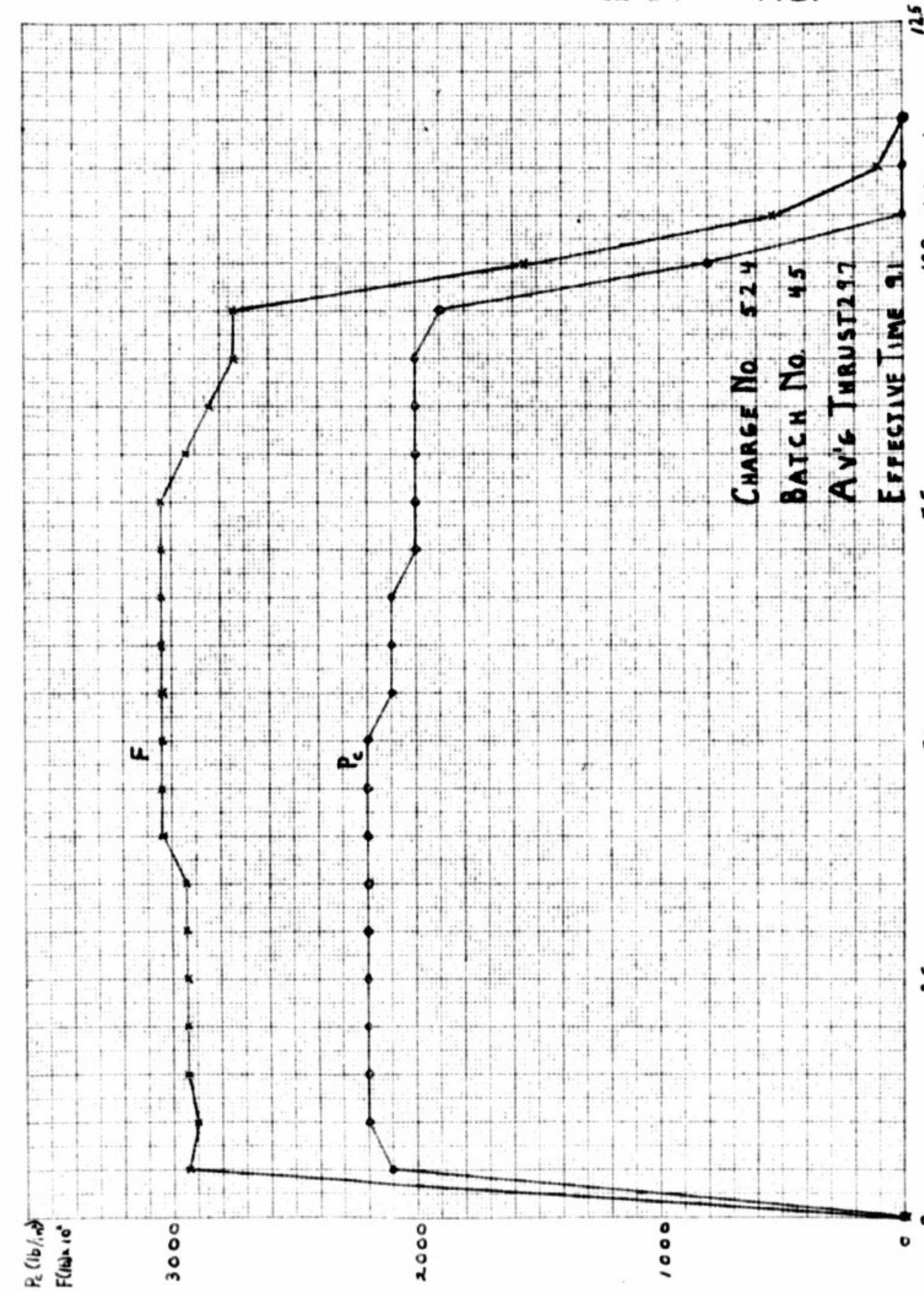
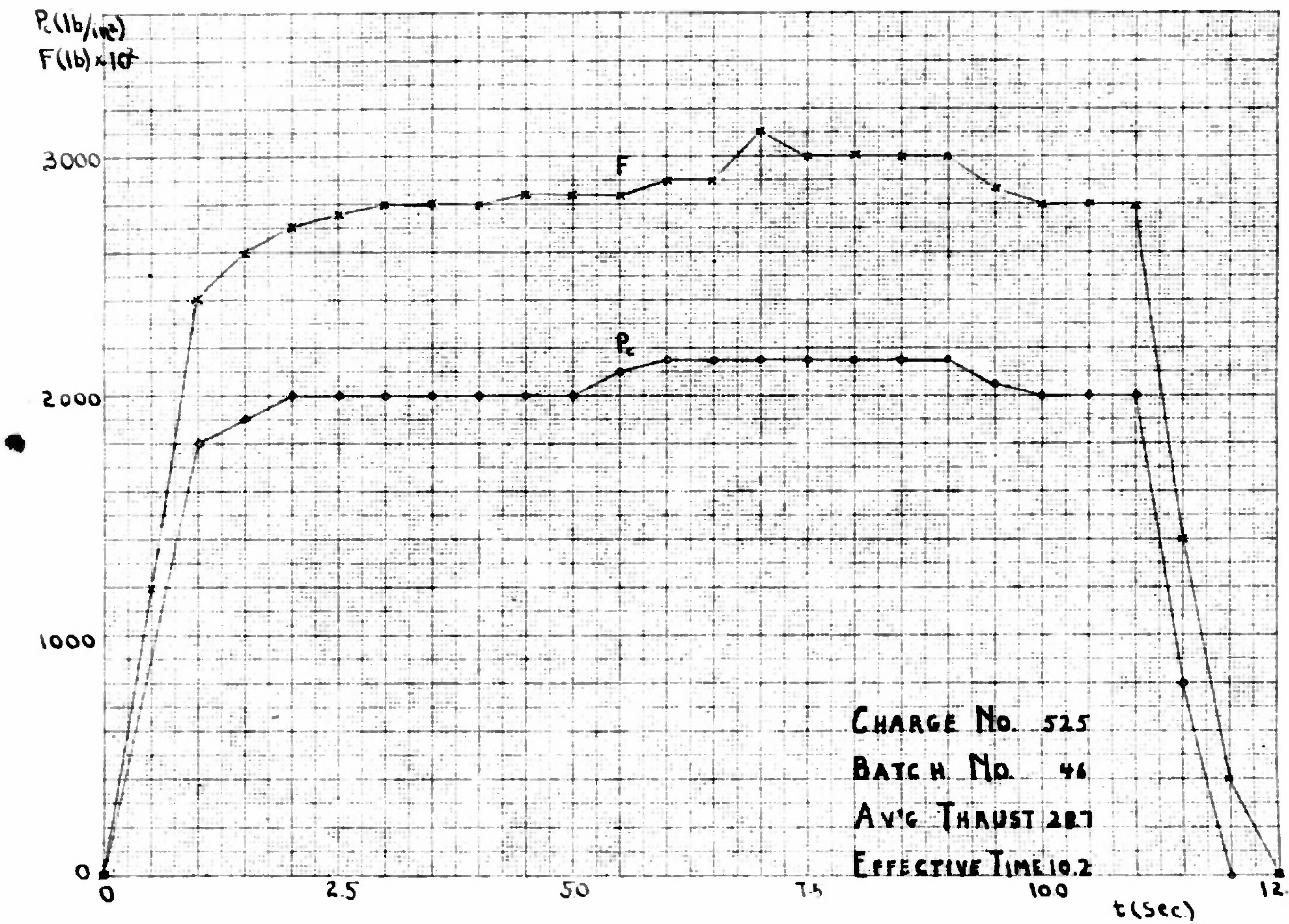
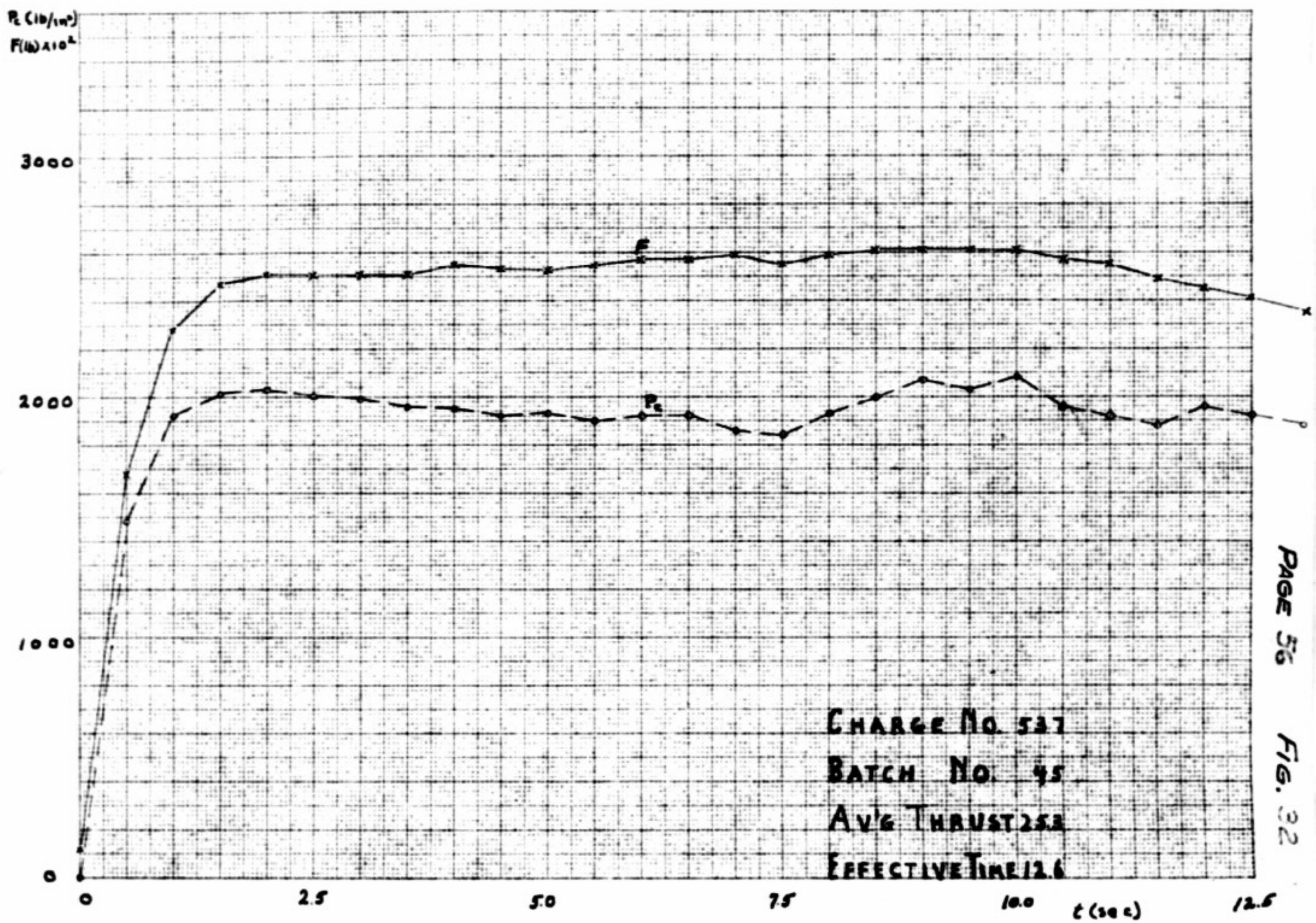

P_c (lb/in²)
F (lb) x 10²
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12
t (sec.)
F
P_c
CHARGE NO. 490
BATCH NO. 43
AV'G THRUST 28.2
EFFECTIVE TIME 10.3

FIG. 30

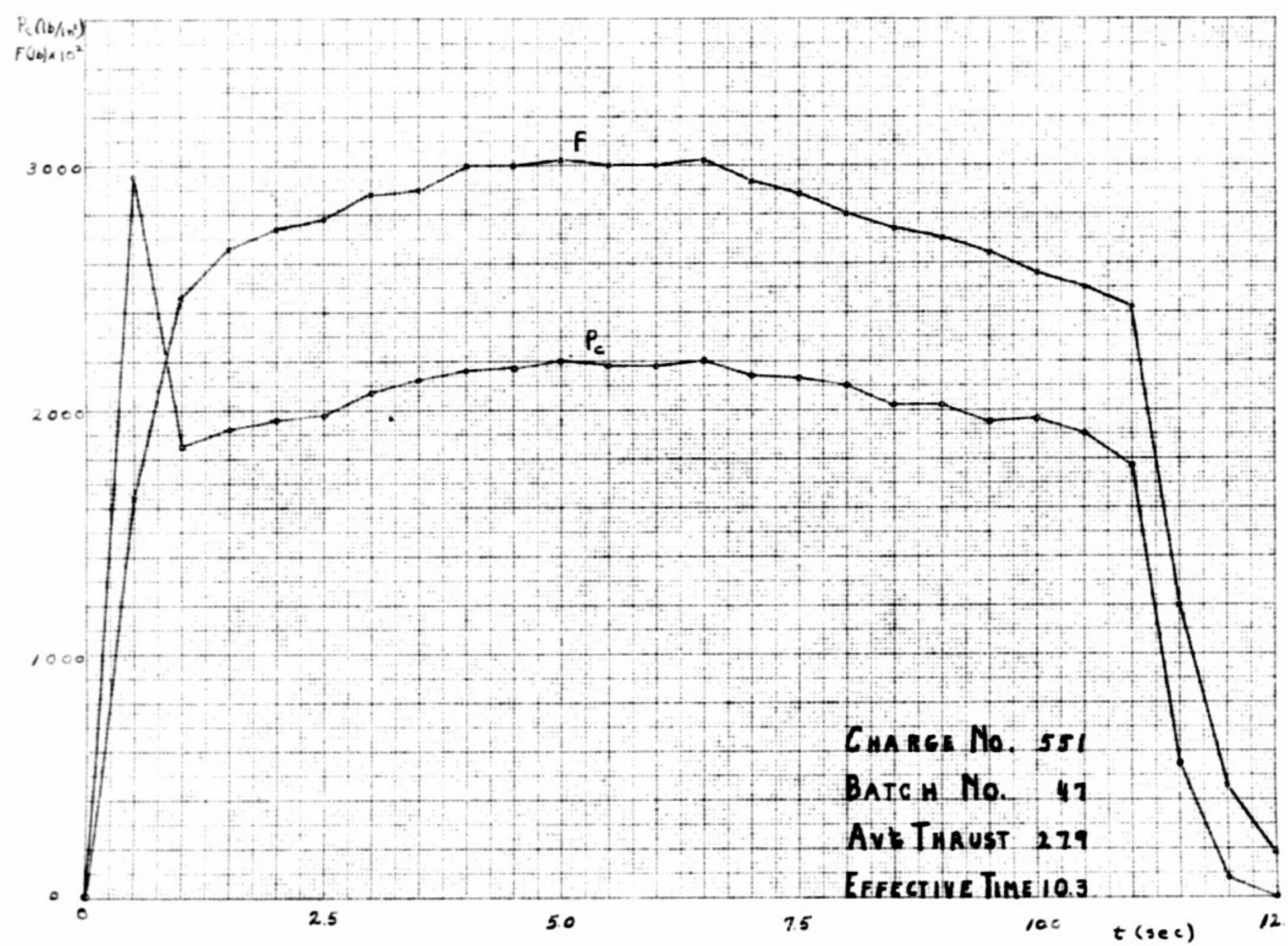

P_c (lb/in^2)
F(lb) x 10
3000
2000
1000
0
0
25
50
75
100
t (sec)
125
F
P_c
CHARGE NO 524
BATCH NO. 45
AV'G THRUST 297
EFFECTIVE TIME 9.1


P_c (lb/in²)
F (lb) x 10
3000
2000
1000
0
F
P_c
0
2.5
5.0
7.5
10.0
12.5
t (Sec)
CHARGE No. 525
BATCH No. 46
AV'G THRUST 2.87
EFFECTIVE TIME 10.2



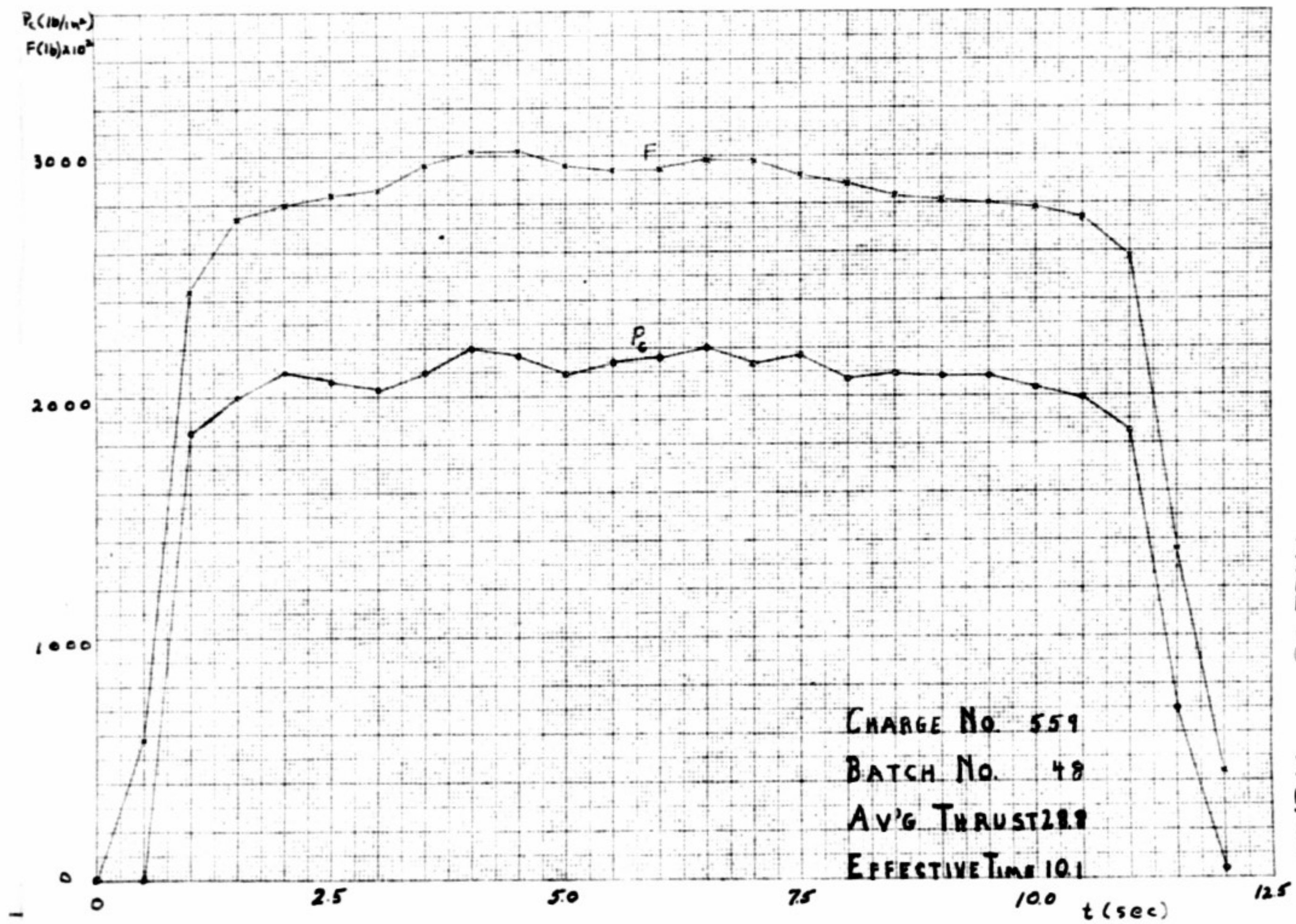
P_c (lb/in²)
F(lb) x 10²
3000
2000
1000
0
0
2.5
5.0
7.5
10.0
12.5
t (sec)
F
P_c
CHARGE NO. 537
BATCH NO. 45
AV'G THRUST 253
EFFECTIVE TIME 12.6

FIG. 32

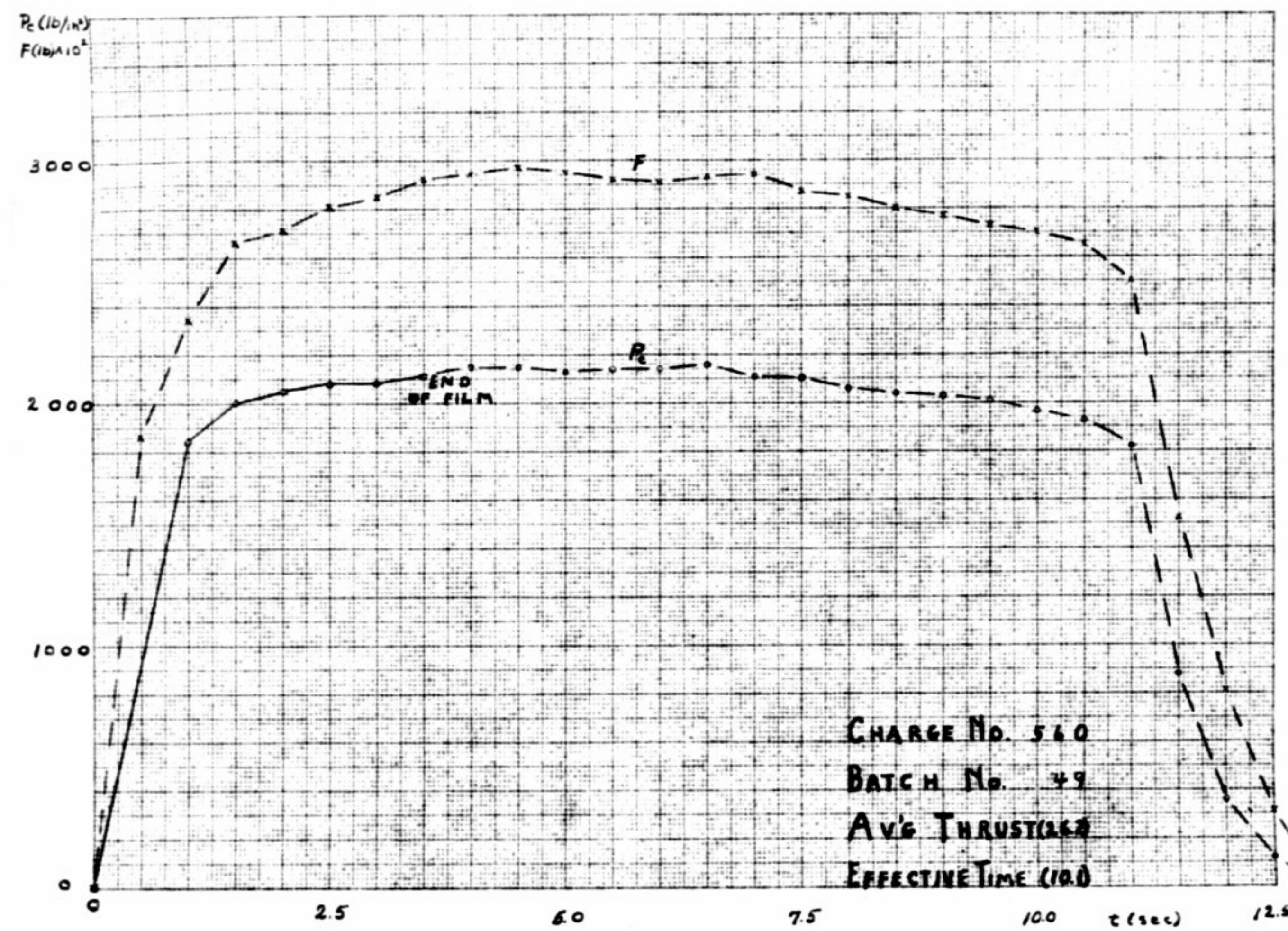


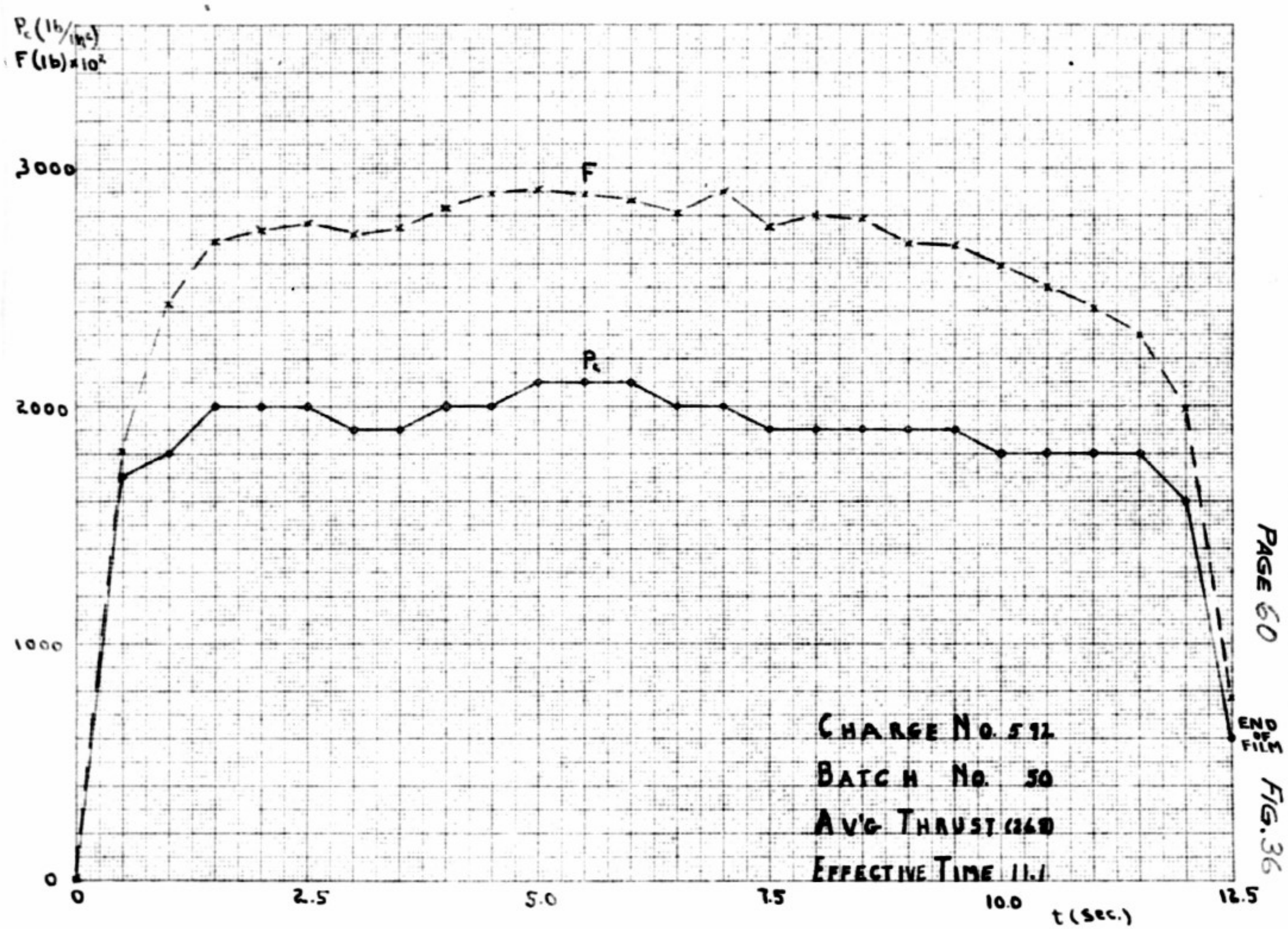
PAGE 57 FIG. 33

FIG. 34



P_c (lb/in²)
F(lb)x10²
3000
2000
1000
0
F
P_c
0
2.5
5.0
7.5
10.0
12.5
t (sec)
CHARGE NO. 559
BATCH NO. 48
AV'G THRUST 28.8
EFFECTIVE TIME 10.1


Pc (lb/in²)
F (lb) x 10²
3000
2000
1000
0
F
Pc
END OF FILM
0
2.5
5.0
7.5
10.0
t (sec)
12.5
CHARGE No. 560
BATCH No. 49
Av'g Thrust
Effective Time (10.1)



PAGE 60

FIG. 36

Fig. 37 -- View showing setup used to measure the static thrust of the propeller.

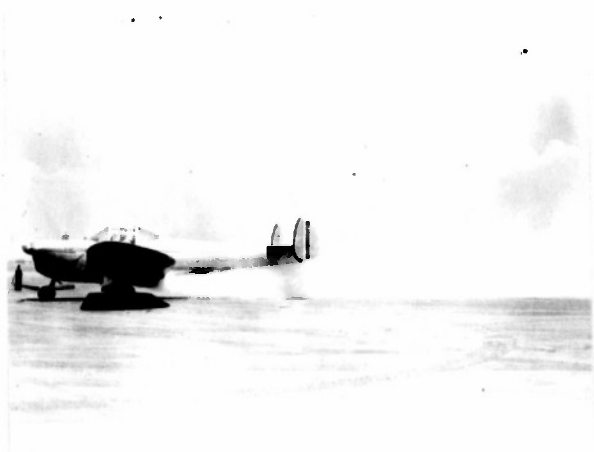


Fig. 38 -- View of first static test with two jet units firing.

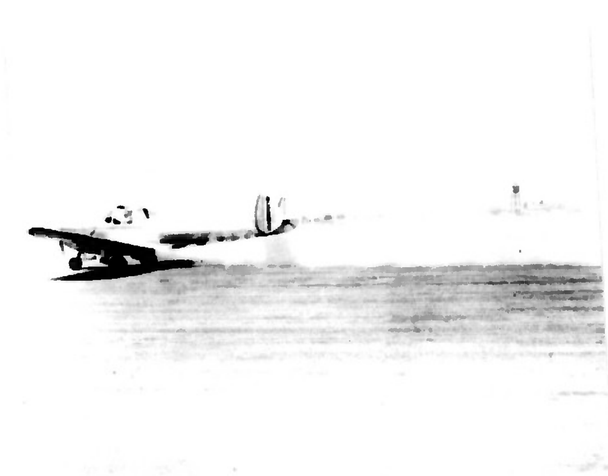


Fig. 39 -- First taxi test with one jet unit firing in each assembly.

Fig. 40 -- Close-up of hole torn at rear of fuselage b exhaust nozzle upon rebounding from runway after jet unit failure.

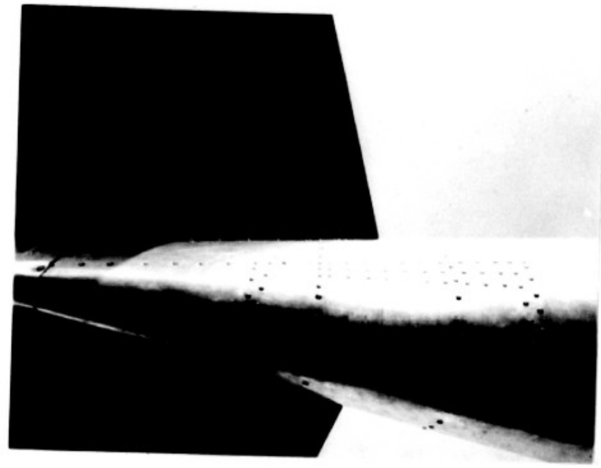


Fig. 41 -- View of repaired fuselage.

Fig. 42 -- Ercoupe about to leave ground on first take-off, August 12, 1941.

Fig. 43 -- Ercoupe assisted by auxiliary jet propulsion about to leave the runway on take-off.

Fig. 44 -- Ercoupe assisted by auxiliary jet propulsion leaving the runway on take-off.

Fig. 45 -- Ercoupe assisted by auxiliary jet propulsion at start of climb after take-off.

Fig. 46 -- Ercoupe assisted by auxiliary jet propulsion in climb after take-off.

Fig. 47 -- Ercoupe assisted by auxiliary jet propulsion in climb after take-off.

Fig. 48 -- Ercoupe assisted by auxiliary jet propulsion in climb after take-off.

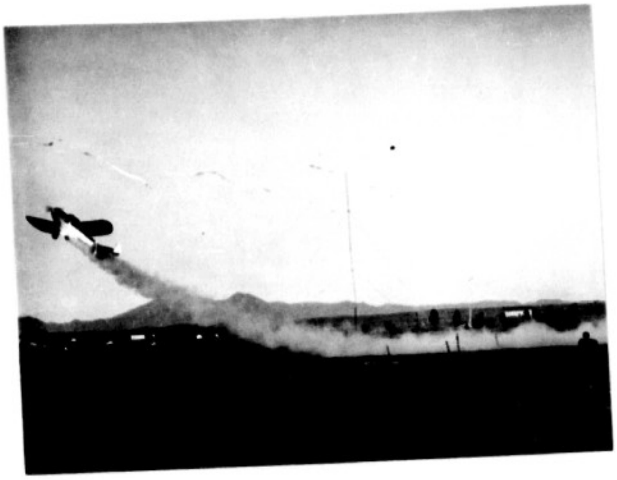


Fig. 49 -- Ercoupe assisted by auxiliary jet propulsion climbing after take-off in 50 ft. obstacle test.

Fig. 50 -- Take-off of Ercoupe assisted by auxiliary jet propulsion compared with a Porterfield airplane.

Fig. 51 -- View of nose of Ercoupe after propeller had been removed.

Fig. 52 -- Run of successful take-off of Ercoupe with jet propulsion alone.

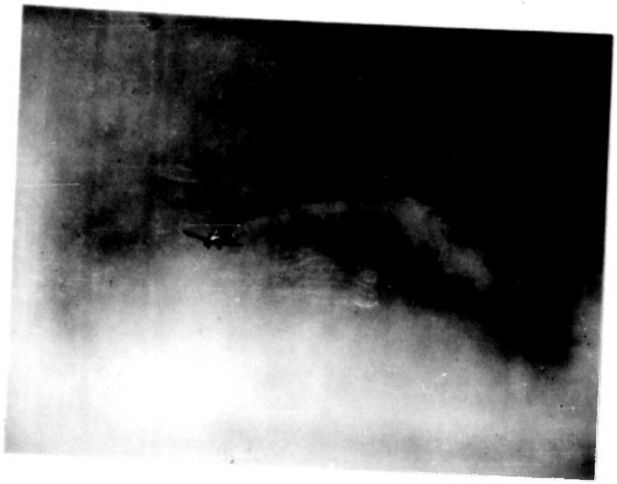
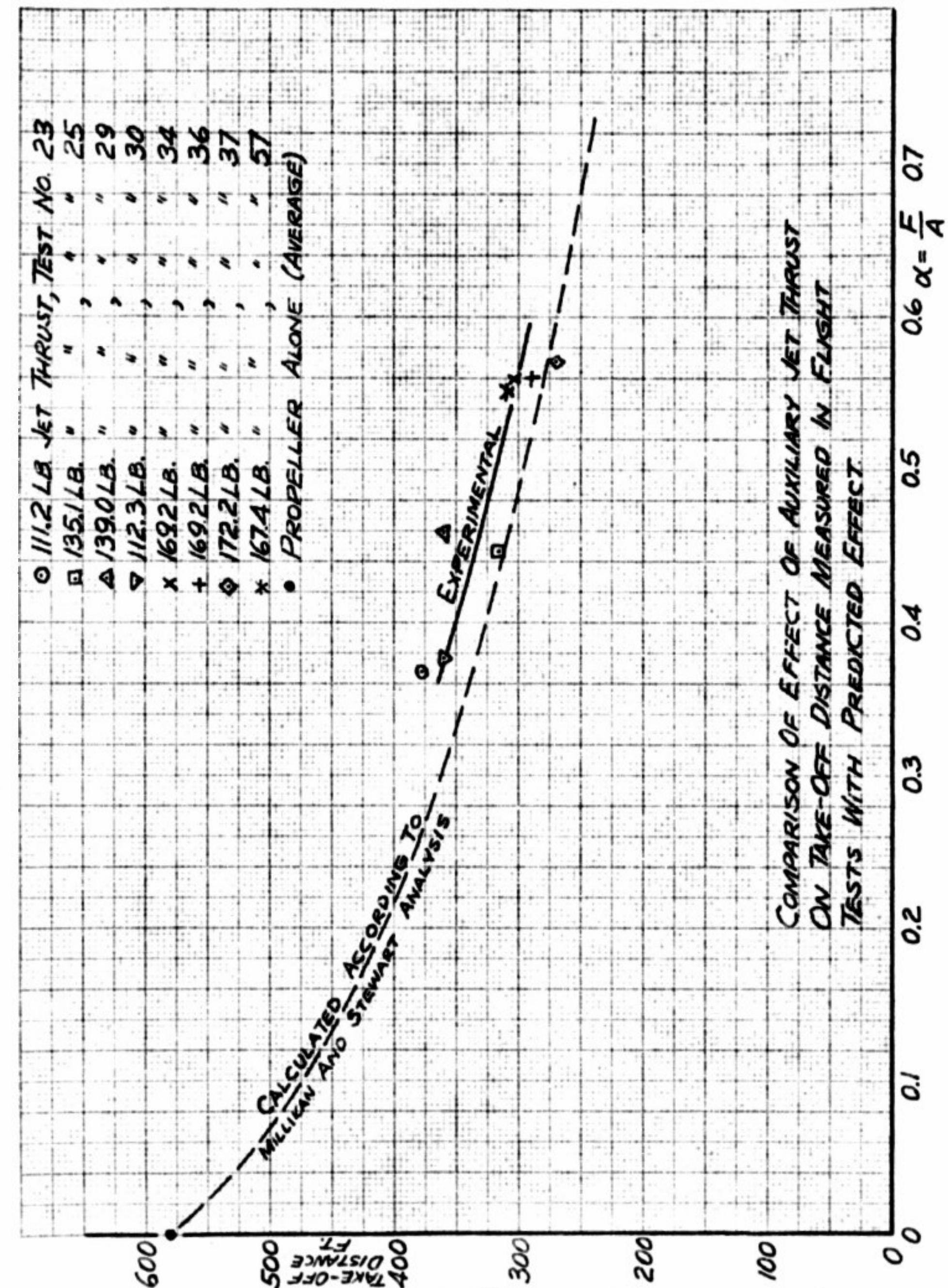
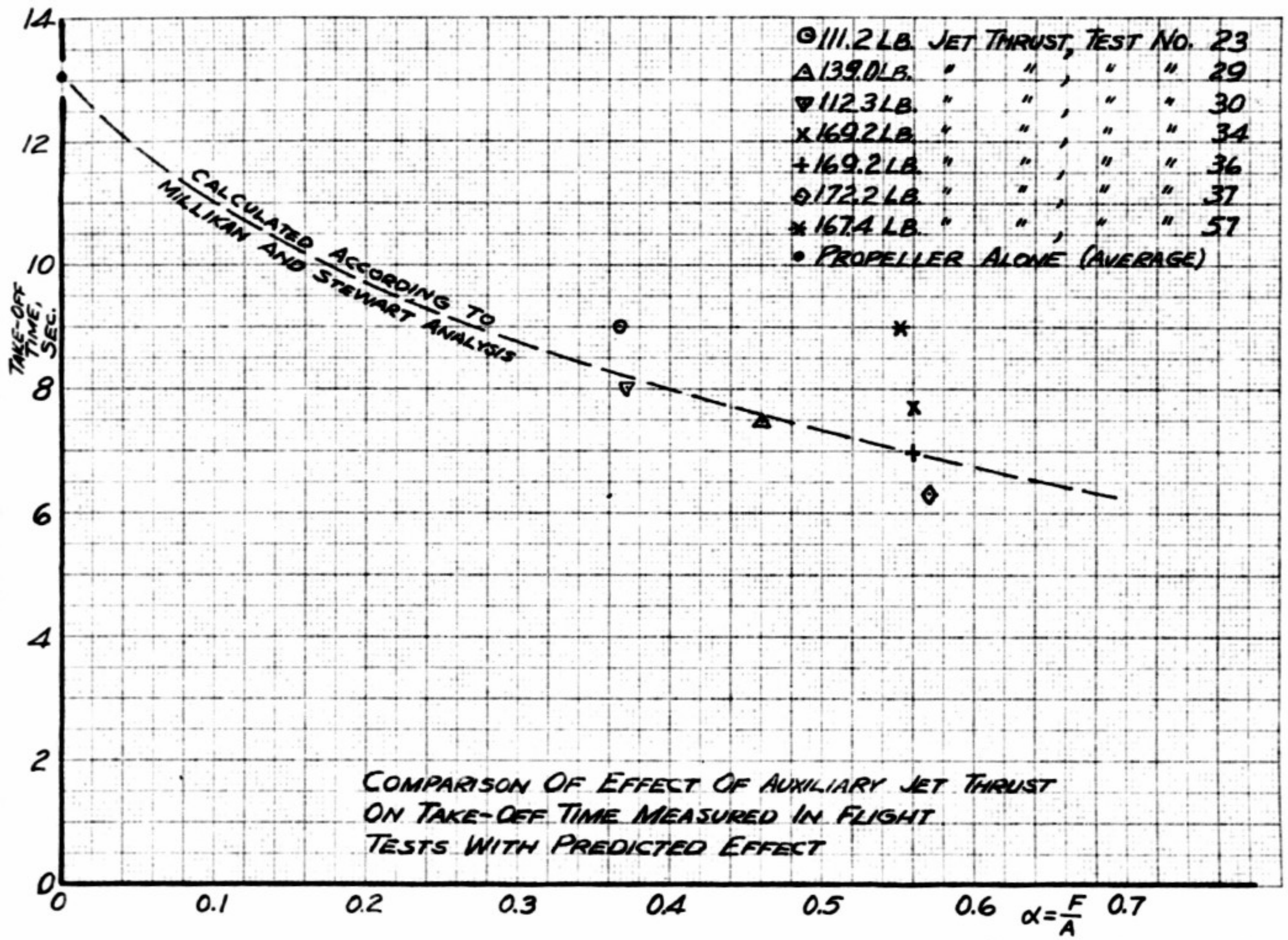


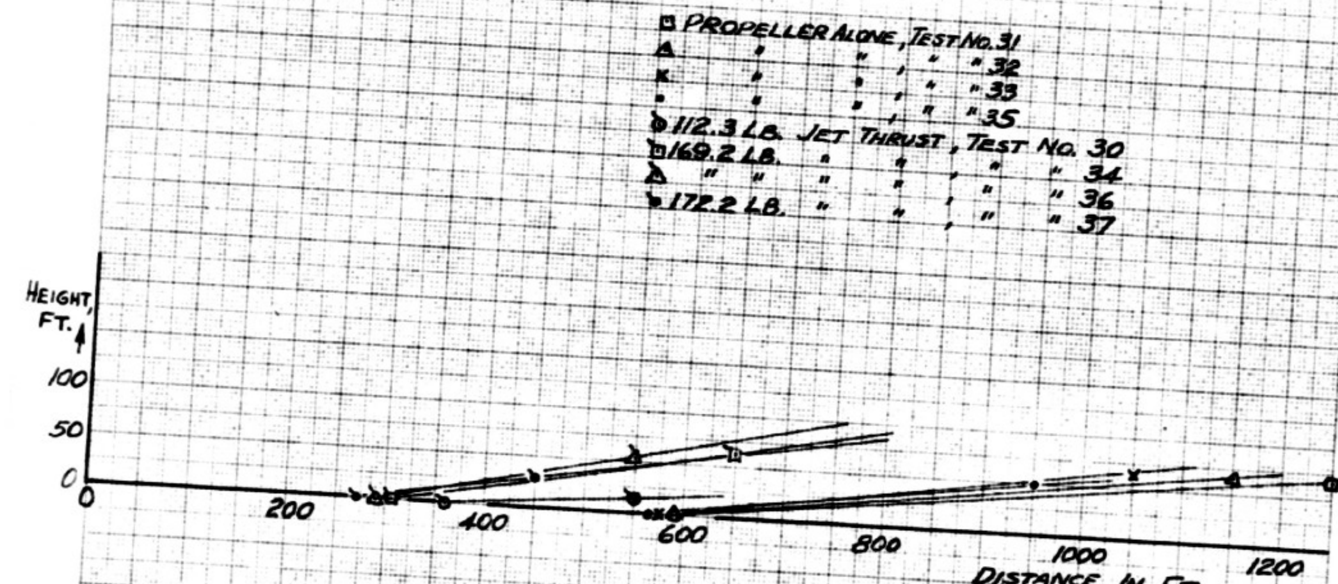
Fig. 53 -- End of climb of last Ercoupe take-off with auxiliary jet propulsion in tests.



COMPARISON OF EFFECT OF AUXILIARY JET THRUST ON TAKE-OFF DISTANCE MEASURED IN FLIGHT TESTS WITH PREDICTED EFFECT.



COMPARISON OF EFFECT OF AUXILIARY JET THRUST ON TAKE-OFF TIME MEASURED IN FLIGHT TESTS WITH PREDICTED EFFECT



GRAPHICAL ILLUSTRATION OF DISTANCE REQUIRED TO CLEAR A 50 FT. OBSTACLE WITH AND WITHOUT AUXILIARY JET THRUST

TABLE II

TEST DATA ON BATCH SAMPLES

CHARGE No.	POWDER TYPE	BATCH No.	DATE OF LOADING	DATE OF RUN	MOTOR No.	NOZZLE No.	RELATIVE HUMIDITY (LOADING) %	RELATIVE HUMIDITY (RUN) %	W_c LB.	l_c IN.	d_c IN.
410	GALCIT27	35	8-5-41	8-5-41	2	2	55.5	54	1.97	11.0	1.75
411	"	36	"	8-7-41	L	4	55	53	"	"	"
416	"	"	"	"	29	12	70	"	1.94	10.7	"
419	"	35	"	8-6-41	M	5	80	46	1.97	"	"
420	"	"	"	"	F	1	"	"	"	10.9	"
427	"	37	8-6-41	8-7-41	5	2(Ou)	66	58	1.88	10.0	"
428	"	38	"	"	7	"	75	60	1.78	9.8	"
434	"	"	"	"	20	8	43	46	1.97	11.4	"
452	"	"	"	8-9-41	7	49	51	61	1.88	10.1	"
453	"	39	8-8-41	"	6	4	53	60	"	10.3	"
454	"	"	8-7-41	"	2	29	55	61	"	"	"
462	"	40	8-10-41	8-10-41	3	70	66	76	1.78	11.0	"
480	"	41	8-12-41	8-12-41	3	2	38	35	1.66	10.0	"
487	"	42	8-13-41	8-13-41	2	"	41	41	1.91	11.0	"
490	"	43	"	"	6	"	31	31	1.72	10.0	"
524	"	45	8-16-41	8-18-41	3	"	51	38	1.75	10.0	"
525	"	46	"	"	2	"	51	38	"	"	"
537	"	45	8-18-41	8-20-41	0	105	41	38	1.81	10.9	"
551	"	47	8-19-41	"	6	2	38	39	1.75	10.6	"
559	"	48	"	"	2	"	65	39	"	9.7	"
560	"	49	"	"	7	"	56	33	"	"	"
592	"	50	8-22-41	8-22-41	"	"	59	60	"	10.6	"

SAMPLES

( ) SIGNIFIES EXTRAPOLATED DATA

RELATIVE HUMIDITY (RUN) %	W_c LB.	l_c IN.	d_c IN.	d_t, IN. INITIAL / FINAL	d_t AV. IN.	d_r IN	d_e/d_t	ϵ	d_c/d_t	f_c/f_t	$\rho_p \times 10^4$ SLUGS/IN³	$t_{tot.}$ SEC.	t_{eff} SEC.	P_{ce} LB/IN²	P_c AV. LB/IN²	$F^*_{AV.}$ LB.	$P_c f_t$ LB.	C_m	C_F	C FT/SEC	r IN/SEC	? IN	α
54	1.97	11.0	1.75	0.093 / 0.089	0.091	0.375	4.11	16.9	19.2	368	1.93	10.5	8.3	3400	3650	39.5	23.9	0.341	1.65	5420	1.33	0.586	14°
53	"	"	"	0.104 / 0.102	0.103	"	3.65	13.3	17.0	290	"	13.5	11.5	(2110)	(2420)	29.7	(20.1)	(0.291)	(1.48)	(5680)	0.96	"	"
"	1.94	10.7	"	0.106 / 0.104	0.105	"	3.56	12.7	16.6	276	1.94	16.0	13.0	(2010)	(2320)	30.0	(20.2)	(0.253)	(1.48)	(6570)	0.83	"	"
46	1.97	"	"	"	"	"	"	"	"	"	1.97	13.0	10.3	(1890)	(2010)	27.1	(17.5)	(0.373)	(1.55)	(4650)	1.05	"	"
"	"	10.9	"	0.104 / 0.102	0.103	"	3.65	13.3	17.0	290	1.95	14.0	11.3	(2160)	(2540)	30.9	(21.1)	(0.283)	(1.47)	(5800)	0.97	"	"
58	1.88	10.0	"	0.102 / 0.100	0.101	0.420	4.16	17.3	17.4	304	2.02	13.0	10.0	2550	2900	33.6	23.0	0.279	1.46	5880	1.00	"	"
60	1.78	9.8	"	0.100 / 0.098	0.099	"	4.25	18.1	17.7	314	1.97	12.0	9.2	2860	3090	34.3	23.6	0.280	1.45	5790	1.06	"	"
46	1.97	11.4	"	0.104 / 0.102	0.103	0.375	3.65	13.3	17.0	290	1.86	13.5	11.3	(1850)	(2260)	28.0	(18.8)	(0.316)	(1.49)	(5260)	1.01	"	"
61	1.88	10.1	"	0.111 / 0.107	0.109	"	3.46	11.9	16.1	259	2.00	(13.0)	(10.5)	(1980)	(1950)	27.0	(18.1)	(0.338)	(1.49)	(4950)	(0.96)	"	"
60	"	10.3	"	0.104 / 0.102	0.103	"	3.65	13.3	17.0	290	1.97	12.5	10.8	1880	2050	27.8	18.4	0.324	1.51	5230	0.95	"	"
61	"	"	"	0.106 / 0.102	0.104	"	3.61	13.0	16.8	283	"	13.5	11.8	1800	2080	28.4	17.7	0.309	1.61	5820	0.87	"	"
76	1.78	11.0	"	0.111 / 0.104	0.108	"	3.49	12.2	16.3	265	1.72	15.0	12.7	"	2010	27.8	18.1	0.265	1.53	6480	"	"	"
35	1.66	10.0	"	0.110 / 0.104	0.107	"	3.50	12.3	16.4	267	1.79	13.0	11.6	2100	2140	26.0	19.2	0.254	1.35	5960	0.96	"	"
41	1.91	11.0	"	0.110 / 0.106	0.108	"	3.46	12.0	16.2	262	1.87	"	10.4	1900	2120	27.7	19.5	0.322	1.42	4940	1.06	"	"
31	1.72	10.0	"	"	"	"	"	"	"	"	1.72	"	10.3	1800	2030	28.2	18.7	0.305	1.51	5530	0.97	"	"
38	1.75	10.0	"	0.110 / 0.104	0.107	"	3.51	12.3	16.4	268	1.87	10.5	9.1	1900	2120	29.7	19.2	0.344	1.55	5060	1.10	"	"
38	"	"	"	"	"	"	"	"	"	"	"	12.5	10.2	2000	2060	28.7	19.0	0.309	1.51	5480	0.98	"	"
38	1.81	10.9	"	0.110 / 0.106	0.108	0.395	3.65	13.3	16.2	262	1.79	14.0	12.6	(1870)	(1950)	25.3	(17.9)	(0.274)	(1.41)	(5770)	0.86	"	"
39	1.75	10.6	"	"	"	0.375	3.46	12.0	"	"	1.76	13.0	10.3	1770	2050	27.9	18.9	0.307	1.47	5380	1.03	"	"
39	"	9.7	"	"	"	"	"	"	"	"	1.92	12.5	10.1	1990	2100	28.8	19.3	0.306	1.49	5460	0.96	"	"
33	"	"	"	"	"	"	"	"	"	"	"	(13.0)	(10.1)	—	2060	(27.9)	19.0	(0.312)	(1.58)	(5660)	(0.96)	"	"
60	"	10.6	"	"	"	"	"	"	"	"	1.76	13.5	11.1	1800	1940	(27.3)	17.9	0.300	(1.53)	(5700)	0.96	"	"

TABLE III
DATA ON JET UNITS USED IN FLIGHT TESTS

CHARGE No.	POWDER TYPE	BATCH No.	DATE OF LOADING	DATE OF RUN	MOTOR No.	NOZZLE No.	RELATIVE HUMIDITY (LOADING) %	l IN.	W_c LB.	l_c IN.	d_c IN.	d_t, IN. INITIAL / FINAL	d_t AV. IN.	d_e IN.	d_e/d_t	ϵ	α	d_c/d_t	f_c/f_t	$\rho_p \times 10^4$ SLUGS/IN.^{3}	$t_{tot.}$ SEC.	t_{eff} SEC.	$P_{AV.}$ LB./IN.^{2}	$F_{AV.}$ LB.	$P_c f_t$ LB.	C_m	C_F	C FT./SEC.	r IN./SEC.
401	GALCIT 27	34	8-4-41	8-6-41	23	55	43	0.586	1.97	11.0	1.75	0.093 / 0.107	0.100	0.375	3.75	14.1	14°	17.5	306	1.93	12.5	10.1	2730	32.5	20.8	0.321	1.56	5440	1.09
402	"	34,35	"	"	19	46	54	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
403	"	35	"	"	17	30	69	"	2.03	"	"	"	"	"	"	"	"	"	"	1.99	"	"	"	"	"	0.331	"	5280	"
405	"	"	"	"	11	57	80	"	1.97	"	"	0.093 / 0.089	0.091	"	4.11	16.9	"	19.2	368	1.93	"	"	"	"	"	0.321	"	5440	"
406	"	"	"	"	K	54	66	"	"	11.1	"	0.094 / 0.102	0.098	"	3.85	14.8	"	18.0	322	1.92	"	10.2	"	"	"	0.317	"	5520	"
408	"	"	"		I		56	"	"	"	"	0.093 / 0.089	0.091	"	4.11	16.9	"	19.2	367	1.91	"	"	"	"	"	"	"	"	"
412	"	36	8-5-41	8-6-41	33	56	57	"	1.94	11.0	"	0.093 / 0.107	0.100	"	3.75	14.1	"	17.5	306	1.90	14.5	12.2	2800	33.1	21.4	0.254	1.54	6790	0.90
413	"	"	"	"	D	51	65	"	1.97	"	"	0.093 / 0.089	0.091	"	4.11	16.9	"	19.2	368	1.93	"	"	"	"	"	0.258	"	6680	"
414	"	"	"	"	E	44	63	"	1.94	10.9	"	"	"	"	"	"	"	"	"	1.92	"	12.1	"	"	"	0.256	"	6740	"
415	"	"	"	"	G	58	"	"	"	11.0	"	"	"	"	"	"	"	"	"	1.90	"	12.2	"	"	"	0.254	"	6790	"
423	"	37	"	"	24	22	73	"	1.88	"	"	"	"	"	"	"	"	"	"	1.84	14.0	11.0	2900	33.6	23.0	"	1.46	6430	1.00
425	"	"	"	8-8-41	23	72	37.5	"	2.06	11.5	"	0.104 / 0.102	0.103	"	3.65	13.3	"	17.0	290	1.98	14.5	11.5	"	"	"	0.266	"	6140	"
436		"	"	"	29	49	"	"	1.97	11.3	"	"	"	"	"	"	"	"	"	1.88	"	11.3	"	"	"	0.259	"	6310	"
439	"	"	"	"	H	39	62	"	"	11.0	"	"	"	"	"	"	"	"	"	1.93	14.0	11.0	"	"	"	0.266	"	6140	"
42?		"	"	"	M	29	60	"	"	10.9	"	"	"	"	"	"	"	"	"	1.95	"	10.9	"	"	"	0.269	"	6080	"
459	"	39	8-10-41	8-12-41	M	34	66	"	1.94	11.5	1.81	0.110 / 0.106	0.108	"	3.46	12.0	"	16.7	250	1.64	14.5	12.7	2080	28.4	17.7	0.245	1.61	6110	0.91
460		"	"	"	E	31	"	"	1.97	"	"		"	"	"	"	"	"	"	1.72	"	"	"	"	"	0.300	"	6000	"
461		"	"	"	19	66	67	"	1.88	"	"	"	"	"	"	"	"	"	"	1.64	"	"	"	"	"	0.286	"	6300	"
466	"	40	8-11-41	"	I	23	54	"	1.97		1.75	"	"	"	"	"	"	16.2	262		15.0	12.8	2010	27.8	18.1	0.291	1.53	5870	0.87
468		"	"	"	32	6.0	50	"	2.03	11.1	"	"	"	"	"	"	"	"	"	1.47	"	"	"	"	"	0.300	"	5700	"
469						DATA MISSING - RUN GOOD																							
470	"	40	8-11-41	8-12-41	G	62	55	0.586	1.94	10.8	1.75	0.110 / 0.106	0.108	0.375	3.46	12.0	14°	16.2	262	1.94	14.5	12.4	2010	27.8	18.1	0.245	1.53	5800	0.87
471	"	39	"	"	H	61	60	"	"	11.0	"	"	"	"	"	"	"	"	"	1.90	14.0	12.1	2180	25.4	17.7	0.310	1.61	5820	0.91
472	"	40	"	"	23	67	65	"	"	"	"	"	"	"	"	"	"	"	"	"	15.0	12.6	2010	27.5	18.1	0.291	1.53	5780	0.87
473	"	"	"	"	N	64	71	"	"	10.8	"	"	"	"	"	"	"	"	"	1.94	14.5	12.4	"	"	"	0.245	"	6110	"
474	"	"	"	"	24	65	76	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
475	"	"	"	"	A	54	80	"	"	11.0	"	"	"	"	"	"	"	"	"	1.90	15.0	12.6	"	"	"	0.241	"	5880	"
476	"	41	8-12-41	8-14-41	29	18	60	"	1.97	10.9	"	"	"	"	"	"	"	"	"	1.75	13.0	11.4	2140	26.0	19.2	0.308	1.35	4910	0.96
477	"	40	"	"	21	30	44	"	1.94	11.0	"	0.113 / 0.111	0.112	0.395	3.53	12.4	"	15.6	244	1.90	15.0	12.6	2010	27.8	18.1	0.291	1.53	5880	0.57
479	"	41	"	"	C	77	33	"	1.85	10.6	"	0.110 / 0.100	0.105	"	3.65	13.3	"	16.2	262	1.77	12.5	11.1	2140	26.0	19.2	0.274	1.35	5140	0.46
481	"	"	"	"	28	34	43	"	1.75	10.8	"	"	"	"	"	"	"	"	"	1.74	"	11.3	"	"	"	0.276	"	5480	"
482	"	"	"	"	N	44	42	"	1.94	11.0	"	"	"	"	"	"	"	"	"	1.90	13.0	11.5	"	"	"	0.300	"	5040	"

TABLE IV
DATA ON JET UNITS USED IN FLIGHT TESTS

Charge No.	Powder Type	Batch No.	Date of Loading	Date of Run	Motor No.	Nozzle No.	Relative Humidity (Loading) %	l In.	W_c Lb.	l_c In.	d_c In.	d_t, In. Initial / Final	d_t Av. In.	d_e In.	d_e/d_t	ϵ	d_c/d_t	f_c/f_t	α	$\beta \times 10^4$ Slugs/In²	t_{tot} Sec.	t_{eff} Sec.	P_c Av. Lb/In²	$F_{Av.}$ Lb.	$P_c f_t$ Lb.	C_m	C_F	C Ft/Sec.	r In/Sec.		
483	GALCIT 27	41	8-12-41	8-14-41	23	31	43	0.586	1.94	11.0	1.75	0.110 / 0.106	0.108	0.395	3.65	13.3	16.2	262	14°	1.90	13.0	11.5	2140	26.0	14.2	0.300	1.35	5040	0.96		
484	"	"	"	"	F	52	50	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
486	"	"	8-13-41	"	19	30	41.5	"	1.88	10.8	"	0.111 / 0.110	0.111	"	3.58	12.8	15.5	251	"	1.88	12.5	11.2	"	"	"	0.299	"	5060	"		
489	"	42	"	"	17	84	34	"	"	"	"	0.110 / 0.106	0.108	"	3.65	13.3	16.2	262	"	"	13.0	10.2	2120	27.7	19.5	0.323	1.42	4940	1.06		
491	"	"	"	"	25	74	24.5	"	1.94	11.0	"	"	"	"	"	"	"	"		1.90	"	10.4	"	"	"	0.327	"	4860	"		
492	"	43,42	"	"	20	87	23	"	1.88	"	"	"	"	"	"	"	"	"	"	1.84	13.5	10.8	2010	28.0	19.1	0.312	1.47	5280	1.02		
493	"	43	"	"	27	84	25	"	1.94	"	"	"	"	"	"	"	"	"	"	1.90	14.0	11.3	2030	28.2	18.7	0.314	1.51	5380	0.97		
494	"	42	"	"	24	73	37	"	"	"	"	"	"	"	"	"	"	"	"	"	13.0	10.4	2120	27.7	19.5	0.327	1.42	4860	1.06		
495	"	"	"	"	G	80	42	"	"	"	"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
496	"	"	"	8-6-41	M	89	50	"	"	"	"	"		0.375	3.46	12.0	"	"	"	"	"	"	"	"	"	"	"	"	"		
497	"	"	"	8-4-41	E	85	45	"	1.88	10.8	"	"	"	0.395	3.65	13.3	"	"	"	1.85	"	10.2	"	"	"	0.323	"	4940	"		
498	"	"	"	"	15	88	54	"	"	11.0	"	"	"	"	"	"		"	"	1.84	"	10.4	"	"	"	0.317	"	5520	"		
499	"	"	"	"	33	72		"	1.94	"	"	"	"	"	"	"		"	"	1.90	"	"	"	"	"	0.327	"	4860	"		
500	"	"	"	8-16-41	25	79	41	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
501	"	"	8-14-41	"	33	23	24	"	"	"	"	0.111 / 0.110	0.111	"	3.58	12.8	15.8	251	"	1.88	"	"	"	"	"	"	"	"	"		
502	"	43	"	"	A	93	33.5	"	1.88	10.8	"	0.110 / 0.106	0.108	"	3.65	13.3	16.2	262	"	"	14.0	11.1	2030	28.2	18.7	0.310	1.51	5450	0.97		
503	"	"	"	8-18-41	O	78	72	"	"	10.5	"	0.111 / 0.110	0.111	"	3.58	12.8	15.8	251	"	1.93	13.5	10.8	"	"	"	0.318	"	5320	"		
504	"	"	8-13-41	8-16-41	F	94	82	"	1.94	11.0	"	0.110 / 0.106	0.108	0.375	3.46	12.0	16.2	262	"	1.90	14.0	11.3	"	"	"	0.314	"	5380	"		
505	"	"	8-14-41	"	E	91	71	"	"	"	"	"	"	0.395	3.65	13.3	"	"	"	"	"	"	"	"	"	"	"	"	"		
506	"	"	"	8-15-41	C	89	54	"		10.8	"	0.111 / 0.110	0.111	"	3.58	12.8	15.8	251		1.94	"	11.1	"	"	"	0.319	"	5300	"		
507	"	"	"	8-16-41	N	83	62	"	"	"	"	0.110 / 0.106	0.108	"	3.65	13.3	16.2	262	"	"	"	"	"	"	"	0.320	"	5280	"		
508	"	"	"	"	G	87	71	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
510	"	"	8-15-41	"	17	42	61	"	"	10.5	"	"	"	"	"	"	"	"	"	1.99	13.5	10.8	"	"	"	0.328	"	5160	"		
511	"	"	"	"	24	86	64	"	"	10.8	"	"	"	"	"	"	"	"	"	1.94	14.0	11.1	"	"	"	0.320	"	5280	"		
513	"	44	"	"	26	71	71	"	1.81	10.5	"	"	"	"	"	"	"	"	"	1.86	13.0	10.7	2050	29.0	19.0	0.305	1.53	5620	0.98		
514	"	"	"	"	27	57	52	"	1.94	10.8	"	"	"	"	"	"	"	"	"	1.94	"	11.0	"	"	"	0.317	"	5400	"		
515	"	"	"	"	20	90	75	"	1.81	10.3	"	"	"	"	"	"	"	"	"	1.90	12.5	10.5	"	"	"	0.310	"	5520	"		
516	"	"	"	"	K	76	70	"	1.94		"	"	"	"	"	"	"	"	"		13.0	10.7	"	"	"	0.326	"	5260	"		
517	"	"	"	"	L	45	67	"	"	11.0	"	"	"	"	"	"	"	"	"	1.90	13.5	11.2	"	"	"	0.312	"	5490	"		
518	"	"	"	"	O	75	54	"	"	10.8	"	"	"	"	"	"	"	"	"	1.94	13.0	11.0	"	"	"	0.317	"	5400	"		
519	"	"	"	"	P	73	"	"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
520	"	"	"	"	Q	52	61	"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		

TABLE V
DATA ON JET UNITS USED IN FLIGHT TESTS

Charge No.	Powder Type	Batch No.	Date of Loading	Date of Run	Motor No.	Nozzle No.	Relative Humidity (Loading) %	l In.	W_c Lb.	l_c In.	d_c In.	d_t, In. Initial / Final	d_t Av. In.	d_e In.	d_e/d_t	ϵ	α	d_c/d_t	f_c/f_t	$\rho/p \times 10^4$ Slugs/...	t_{tot} Sec.	t_{eff} Sec.	P_c Av. Lb/In²	F Av. Lb.	$P_c f_t$ Lb.	C_m	C_f	C Ft/Sec.	r In/Sec.
523	GALCIT 27	44	8-16-41	8-19-41	R		68	0.586	1.91	11.0	1.75	0.110 / 0.106	0.108	0.395	3.65	13.3	14°	16.2	262	1.87	13.5	11.2	2080	29.0	19.0	0.307	1.53	5580	0.98
526	"	45	"	"	S	98	46	"	1.81	10.8	"	"	"	"	"	"	"	"	"	1.82	12.5	11.0	2040	27.5	18.6	0.302	1.48	5480	"
527	"	"	"	"	U	101	37	"	1.91	11.3	"	"	"	"	"	"	"	"	"	1.83	13.0	11.5	"	"	"	0.305	"	5430	"
528	"	"	"	"	T	102	38	"	"		"	"	"	"	"	"	"	"	"		"	"	"	"	"	"	"	"	"
529	"	"	8-17-41	"	28	99	60	"	1.72	10.9	"	"	"	"	"	"	"	"	"	1.70	12.5	11.1	"	"	"	0.285	"	5810	"
530	"	"	"	"	V	111	54	"	1.81	11.0	"	"	"	"	"	"	"	"	"	1.77	"	11.2	"	"	"	0.297	"	5580	"
532	"	"	"	"	E		50	"	1.91	"	"	"	"	"	"	"	"	"	"	1.87	"	"	"	"	"	0.313	"	5290	"
533	"	"	"	"	23		51	"	1.81	10.9	"	"	"	"	"	"	"	"	"	1.79	"	11.1	"	"	"	0.300	"	5520	"
534	"	"	8-18-41	"	L		46	"	1.91	11.1	"	"	"	"	"	"	"	"	"	1.85	"	11.3	"	"	"	0.311	"	5320	"
535	"	"	"	"	17		49	"	"	11.3	"	"	"	"	"	"	"	"	"	"	13.0	11.5	"	"	"	0.305	"	5430	"
536	"	"	"	"	25		44	"	"	11.1	"	"	"	"	"	"	"	"	"	1.53	12.5	11.3	"	"	"	0.311	"	5320	"
538	"	46	"	"	Q		42	"	1.88	11.0	"	"	"	"	"	"	"	"	"	1.54	13.5	11.2	2060	28.7	19.0	0.302	1.51	5600	"
539	"	"	"	"	P	113	33	"	1.91	11.1	"	"	"	"	"	"	"	"	"	1.85	"	11.3	"	"	"	0.304	"	5560	"
540	"	"	"	"	N	110	29	"	"	11.0	"	"	"	"	"	"	"	"	"	1.87	"	11.2	"	"	"	0.307	"	5510	"
541	"	"	"	"	F	107	33	"	"	11.1	"	"	"	"	"	"	"	"	"	1.85	"	11.3	"	"	"	0.304	"	5560	"
542	"	"	"	"	K	108	31	"	"	11.3	"	"	"	"	"	"	"	"	"	1.83	14.0	11.5	"	"	"	0.299	"	5660	"
543	"	"	"	"	G	112	32	"	1.81	10.9	"	"	"	"	"	"	"	"	"	1.79	13.5	11.1	"	"	"	0.294	"	5760	"
544	"	"	"	"	M	109	40	"	1.91	11.1	"	"	"	"	"	"	"	"	"	1.55	"	11.3	"	"	"	0.304	"	5560	"
545	"	"	"	8-21-41	A	116	50	"	"	11.0	"	"	"	"	"	"	"	"	"	1.87	"	11.2	"	"	"	0.307	"	5510	"
546	"	"	"	"	20	122	57	"	"	10.9	"	"	"	"	"	"	"	"	"	1.89	"	11.1	"	"	"	0.310	"	5460	"
547	"	"	"	"	29	125	54	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
548	"	"	"	"	26	128	57	"	"	11.0	"	"	"	"	"	"	"	"	"	1.87	"	11.2	"	"	"	0.307	"	5510	"
549	"	47	8-19-41	"	18	129	38	"	"	"	"	"	"	"	"	"	"	"	"	"	"	10.7	2050	27.9	18.9	0.323	1.47	5100	1.03
550	"	"	"	"	24	121	35	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
552	"	"	"	"	D	133	38	"	"	11.1	"	"	"	"	"	"	"	"	"	1.55	"	10.8	"	"	"	0.320	"	5140	"
553	"	"	"	"	B	126	45	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
554	"	"	"	"	27	131	33	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
555	"	"	"	"	32	134	31	"	1.81	11.0	"	"	"	"	"	"	"	"	"	1.77	"	10.7	"	"	"	0.306	"	5380	"
556	"	"	"	"	C	137	46	"	1.91	"	"	"	"	"	"	"	"	"	"	1.57	"	"	"	"	"	0.323	"	5100	"
557	"	"	"	"	I	130	43	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
558	"	"	"	"	33	119	50	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
561	"	"	8-20-41	"	K	127	53	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

TABLE VI

DATA ON JET UNITS USED IN FLIGHT TESTS

Charge No.	Powder Type	Batch No.	Date of Loading	Date of Run	Motor No.	Nozzle No.	Relative Humidity (Loading) %	l In.	W_c Lb.	l_c In.	d_c In.	d_t, In. Initial / Final	$d_{t\,Av.}$ In.	d_e In.	d_e/d_t	ϵ	α	d_c/d_t	f_c/f_t	$\rho_p \times 10^4$ Slugs/In³	t_{tot} Sec.	t_{eff} Sec.	$P_{c\,Av.}$ Lb/In²	$F_{Av.}$ Lb.	$P_c f_t$ Lb.	C_m	C_f	C Ft./Sec.	r In./Sec.		
562	GALCIT 27	47	8-20-41	8-21-41	T	132	43	0.586	1.91	11.0	1.75	0.110 / 0.106	0.108	0.395	3.65	13.3	14°	16.2	262	1.87	13.5	10.7	2050	27.9	18.9	0.323	1.47	5100	1.03		
563	"	"	"	"	R	117	42.5	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
565	"	"	"	"	F	118	39	"	"	11.3	"	"	"	"	"	"	"	"	"	1.83	"	11.0	"	"	"	0.314	"	5240	"		
566	"	48	"	"	L	123	33	"	"	11.0	"	"	"	"	"	"	"	"	"	1.87	14.0	11.4	2100	28.8	19.3	0.297	1.49	5620	0.96		
567	"	"	"	"	G	124	37	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
568	"	"	"	"	S	120	42	"	1.81	"	"	"	"	"	"	"	"	"	"	1.77	"	"	"	"	"	0.281	"	5940	"		
569	"	"	"	8-23-41	G	156	"	"	1.91	"	"	"	"	"	"	"	"	"	"	1.87	"	"	"	"	"	0.297	"	5620	"		
570	"	"	"	"	U	154	55	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
571	"	"	"	"	V	141	67	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
572	"	"	"	"	P	136	63	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
573	"	"	8-21-41	"	N	144	59	"	"	11.1	"	"	"	"	"	"	"	"	"	1.85	"	11.5	"	"	"	0.274	"	5670	"		
574	"	"	"	"	E	152	54	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
575	"	49	"	"	19	145	61	"	"	"	"	"	"	"	"	"	"	"	"	"	14.5	"	2060	27.9	19.0	0.299	1.58	5920	"		
576	"	"	"	"	21	141	56	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
577	"	"	"	"	31	147	54	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
578	"	"	"	"	17	155	56.5	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
579	"	48,49	"	"	23	153	62	"	"	11.0	"	"	"	"	"	"	"	"	"	1.87	14.0	11.4	2080	28.4	19.2	0.298	1.54	5560	"		
580	"	49	"	"	25	150	63	"	"	"	"	"	"	"	"	"	"	"	"	"	14.5	"	2060	27.9	19.0	0.302	1.58	5860	"		
581	"	"	"	"	S	139	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	0.301	"	5850	"		
582	"	"	"	"	T	151	65	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
583	"	"	"	"	A	142	79	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
584	"	"	"	"	K	146	80	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
585	"	"	"	"	R	138	82	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
586	"	"	"	"	C	148	88	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
587	"	49,50	"	"	28	157	"	"	"	"	"	"	"	"	"	"	"	"	"	"	14.0	"	2000	27.6	18.5	0.310	1.56	5630	"		
588	"	50	"	"	G	160	89	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	1940	27.3	17.9	0.320	1.53	5360	"		
589	"	"	8-22-41	"	D	158	65	"	"	11.1	"	"	"	"	"	"	"	"	"	1.85	"	11.5	"	"	"	0.317	"	5400	"		
590	"	"	"	"	B	143	62	"	1.81	10.9	"	"	"	"	"	"	"	"	"	1.79	13.5	11.3	"	"	"	0.306	"	5600	"		
591	"	"	"	"	L	135	60	"	1.88	11.0	"	"	"	"	"	"	"	"	"	1.84	14.0	11.4	"	"	"	0.315	"	5440	"		
592	"	"	"	"	33	140	"	"	1.91	"	"	"	"	"	"	"	"	"	"	1.87	"	"	"	"	"	0.320	"	5360	"		
594	"	"	"	"	24	91	55	"	"	11.1	"	0.111 / 0.110	0.111	"	3.58	12.8	"	15.8	251	1.85	"	11.5	"	"	"	0.317	"	5400	"		
595	"	"	"	"	20	68	50	"	"	11.0	"	"	"	"	"	"	"	"	"	1.87	"	11.4	"	"	"	0.320	"	5360	"		
596	"	"	"	"	18	93	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		
597	"	"	"	"	26	86	63	"	1.81	10.9	"	"	"	"	"	"	"	"	"	1.79	13.5	11.3	"	"	"	0.306	"	5600	"		
598	"	"	"	"	I	94	65	"	1.91	11.0	"	"	"	"	"	"	"	"	"	1.87	14.0	11.4	"	"	"	0.320	"	5360	"		
599	"	"	"	"	O	89	70	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"		

TABLE VII
DATA ON ERCOUPE FLIGHT TESTS

Test No.	Date	Time of Day	Purpose of Test	No. of Jet Units Fired	Charge Nos. Installed	Thrust Added Lb.	Eff. Time Thrust Acted Sec.	Gross Weight Lb.	Overload Lb.	Est. Wind Speed M.P.H.	Meteo. Sta. Wind Speed M.P.H.	Wind Direction	Take off Distance Ft.	Take off Time Sec.	Distance to Clear Obstacle Ft.	Time to Clear Obstacle Sec.	Height Cleared Ft.	Alt. of Test Above Sea Level Ft.	Airspeed Without Jet M.P.H.	Airspeed With Jet M.P.H.	Rate of Climb Ft./Sec.	Pilot's Reaction & Remarks
1	8 6 41	—	Top Speed & Climb Without Jet Eqp.	—	—	—	—	1178	—	0		—	—	—	—	—	—	4528	104	—	700	
2	"	—	Top Speed & Climb With Jet Eqp.	—	—	—	—	"	—	0		—	—	—	—	—	—	"	92	—	600	
3	"	—	Take-off Without Jet Eqp.	—	—	—	—	"	—	0		—	430	12	—	—	—	1528	—	—	—	
4	"	—	"	—	—	—	—	"	—	0		—	419	12	—	—	—	"	—	—	—	
5	"	—	"	—	—	—	—	"	—	0		—	441	12	—	—	—	"	—	—	—	
6	"	—	"	—	—	—	—	"	—	0		—	402	12	—	—	—	"	—	—	—	
7	"	—	"	—	—	—	—	"	—	0		—	420	12	—	—	—	"	—	—	—	
8	"	—	"	—	—	—	—	"	—	0		—	418	12	—	—	—	"	—	—	—	
9	"	—	Take-off With Attach. of Dummy Units	—	—	—	—	"	—	0		—	582	14	—	—	—	"	—	—	—	
10	"	—	"	—	—	—	—	"	—	8		Head Wind	418	12	—	—	—	"	—	—	—	
11	"	—	"	—	—	—	—	"	—	5		"	460	13	—	—	—	"	—	—	—	
12	"	—	"	—	—	—	—	"	—	12		"	390	11	—	—	—	"	—	—	—	
13	"	—	"	—	—	—	—	"	—	11		"	415	11	—	—	—	"	—	—	—	
14	"	—	"	—	—	—	—	"	—	4		"	450	12	—	—	—	"	—	—	—	
15	"	—	"	—	—	—	—	"	—	7		"	399	12	—	—	—	"	—	—	—	
16	"	12 Noon	Static Thrust	2	401 402	79	10.1	"	—	—	10	West Head Wind	—	—	—	—	—	"	—	—	—	Skin Adjacent To Rocket Nozzles Cool — Jet Clears All Portions Of Tail
17	"	12:30 PM	Taxi	2	403 412	79	10.6	"	—	—	15	"	—	—	—	—	—	"	—	—	—	No Effect Noted Except Slight Acceleration
18	"	1:00 PM	Flight	1	406 413 Blew	39.5	10.2	"	—	—	15	WNW	—	—	—	—	—	4528	—	—	—	Right Jet Unit Blew, No Damage — Could Tell Left Unit Was Delivering Thrust
19	"	3:00 PM	Static Thrust	1	405 Misfire 414 Blew 415 Misfire 423	39.5	11.0	"	—	—	0	—	—	—	—	—	—	1528	—	—	—	Left Unit Blew. Rivets & Nuts At Rear Of Bracket Pulled Loose. Motor Cleared Plane
20	8-8-41	6:30 AM	Static Thrust	3	435 Blew 436 438 439	84	11.1	1178		—	0	—	—	—	—	—	—	1528	—	—	—	Right Unit Blew Rather Violently, Chamber Went About 100 Ft Ahead Of Airplane Before Hitting Ground, Rivets-Nuts Pulled Loose At Rear Of Bracket, Skin Above Nozzle Was Stretched By Blast And 4 or 5 Rivets Pulled Off, Nozzle Rebounded From Ground Damaging Fuselage By Making A 10" Hole In The Skin And Breaking A Bulkhead
21	8 12 41	6:25 AM	Taxi	4	459 460 461 466	111.2	12.7	1178	—	—	0	—	—	—	—	—	—	1528	—	—	—	Noticeable Acceleration
22	"	7:00 AM	Flight	4	468 469 470 471	111.5	12.4	"	—	—	0	—	—	—	—	—	—	4528	75	90	—	Marked Acceleration
23	"	8:30 AM	Take-off	4	472 473 474 475	111.2	12.5	"	—	—	3	SW	377	9	—	—	—	1528	—	—	—	Marked Acceleration, Good Control, Speed Seemed To Increase Immediately After Clearing The Ground, And Good Control During The Air-Borne Portion Of The Jet Units Operation
24	8-14 41	7:10 AM	Taxi	5	476 477 Misfire 479 481 482 489	131.2	11.1	1178	—	0	0	—	—	—	—	—	—	1528	—	—	—	

TABLE VIII
DATA ON ERCOUPE FLIGHT TESTS

Test No.	Date	Time of Day	Purpose of Test	No. of Jet Units Fired	Charge Nos. Installed	Thrust Added Lb.	Eff. Time Thrust Acted Sec.	Gross Weight Lb.	Overload Lb.	Est. Wind Speed M.P.H.	Metro. Sta. Wind Speed M.P.H.	Wind Direction	Take-off Distance Ft.	Take-off Time Sec.	Distance to Clear Obstacle Ft.	Time to Clear Obstacle Sec.	Height Cleared Ft.	Alt. of Test Above Sea Level Ft.	Airspeed Without Jet M.P.H.	Airspeed With Jet M.P.H.	Rate of Climb Ft./Sec.	Pilot's Reaction & Remarks
25	8-14-41	8:00AM	TAKE OFF	5	493 494 486 MISFIRE 491 492 495	135.1	10.9	1178	—	5-	0	HEAD WIND	315	9-	—	—	—	1528	—	—	—	
26	8-14-41	8:15AM	TAKE OFF & DUMMY UNITS	—	—	—	—	1178	—	2	2	E CROSS WIND	480	11.5-12	—	—	—	1528	—	—	—	
27	"	8:20AM	" "	—	—	—	—	"	—	"	"	"	485	11.5	—	—	—	"	—	—	—	
28	"	8:25AM	" "	—	—	—	—	"	—	"	"	"	500	11.5-12	—	—	—	"	—	—	—	
29	"	8:55AM	TAKE OFF	5	493 494 497 498 499 496 MISFIRE	139.0	10.5	"	—	"	0	"	360	7.5	—	—	—	"	—	—	—	
30	8-16-41	6:52AM	TAKE OFF OVER OBSTACLE	4	503 MISFIRE 506 " 502 501 504 505	112.3	11.0	1178	—	4-	2	E CROSS WIND	360	8	550	10	15	1528	—	—	—	
31	8-16-41	7:15AM	TAKE OFF OVER OBSTACLE - & DUMMY UNITS	—	—	—	—	1178	—	5-	3	ENE	590	13	1250	22	65-70	1528	—	—	—	
32	"	7:20AM	"	—	—	—	—	"	—	"	"	"	"	13	1150	—	"	"	—	—	—	
33	"	7:25AM	"	—	—	—	—	"	—	"	"	"	575	12.5	1050	20	65	"	—	—	—	
34	"	7:43AM	TAKE OFF OVER OBSTACLE	6	507 508 510 511 513 514	169.2	11.0	"	—	"	"	ESE	305	7.75	650	14	60	"	—	—	—	
35	8-16-41	7:45AM	TAKE OFF OVER OBSTACLE - & DUMMY UNITS	—	—	—	—	1178	—	3-	3	ESE	565	12	950	19	50	1528	—	—	—	
36	"	8:23AM	TAKE OFF OVER OBSTACLE	6	515 516 517 518 519 520	169.2	10.9	"	—	4-	"	E CROSS WIND	290	7	550	10	55	"	—	—	—	
37	8-19-41	7:03AM	TAKE OFF OVER OBSTACLE	6	539 540 541 542 543 544	172.2	11.3	1175	—	3-	0	SLIGHT HEAD WIND	270	6.33	450	12	30	1528	—	—	—	
38	8-19-41	7:10AM	TAKE OFF & DUMMY UNITS	—	—	—	—	1175	—	3-	0	SLIGHT HEAD WIND	465	11	—	—	—	1528	—	—	—	
39	"	7:20AM	TAKE OFF - & DUMMY UNITS & OVERLOAD	—	—	—	—	1338	160	4-	"	"	800 TO 900	15.5	—	—	—	"	—	—	—	
40	"	7:25AM	"	—	—	—	—	1413	235	3-	"	"	915	18	—	—	—	"	—	—	—	
41	"	7:31AM	"	—	—	—	—	1463	285	4-	"	"	955	19.5	—	—	—	"	—	—	—	
42	"	7:53AM	TAKE OFF & OVERLOAD	6	525 526 527 528 529 530	165.7	11.3	"	"	"	3	SSE	460	10	—	—	—	"	—	—	—	

TABLE IX
DATA ON ERCOUPE FLIGHT TESTS

TEST No.	DATE	TIME OF DAY	PURPOSE OF TEST	NO OF JET UNITS FIRED	CHARGE NOS. INSTALLED	THRUST ADDED LB.	EFF. TIME THRUST ACTED SEC.	GROSS WEIGHT LB.	OVERLOAD LB.	EST. WIND SPEED M.P.H.	HTRG. STA. WIND SPEED M.P.H.	WIND DIRECTION	TAKE-OFF DISTANCE FT.	TAKE-OFF TIME SEC.	DISTANCE TO CLEAR OBSTACLE FT.	TIME TO CLEAR OBSTACLE SEC.	HEIGHT CLEARED FT.	ALT. OF TEST ABOVE SEA LEVEL FT.	AIRSPEED WITHOUT JET M.P.H.	AIRSPEED WITH JET M.P.H.	RATE OF CLIMB FT./SEC.	PILOT'S REACTION & REMARKS
43	8-19-41	8:00AM	TAKE-OFF, OVERLOAD + 6 DUMMY UNITS	—	—	—	—	1462	285	4-	3	SSE	825	18	—	—	—	1528	—	—	—	
44	"	8:07AM	"	—	—	—	—	"	"	2	"	"	940	19	—	—	—	"	—	—	—	
45	"	8:15AM	"	—	—	—	—	"	"	3	"	"	900	18.5	—	—	—	"	—	—	—	
46	"	8:44AM	TAKE-OFF + OVERLOAD	6	532 533 534 535 536 538	166.2	11.3	"	"	4-	2	"	415	9	—	—	—	"	—	—	—	
47	8-21-41	6:00AM	TAKE-OFF 6 LOADED UNITS	—	—	—	—	1178	—	0	0	—	635	—	—	—	—	1528	—	—	—	TAKE-OFF LONGER BECAUSE MOTOR NOT WARM ENOUGH.
48	"	6:51AM	FLIGHT AT ALT. WITH JET UNITS	6	545 546 547 548 549 550	170.6	11.0	"	—	—	—	—	—	—	—	—	—	11,400	62	97	—	R.P.M. IN FLIGHT WENT FROM 2200 TO 2400.
49	8-21-41	7:23AM	TAKE-OFF 6 DUMMY UNITS	—	—	—	—	1178	—	1+	2	SSE CROSS WIND	582	13.5	—	—	—	1528	—	—	—	
50	"	7:25AM	"	—	—	—	—	"	—	"	"	"	545	12.2	—	—	—	"	—	—	—	
51	"	7:27AM	"	—	—	—	—	"	—	"	"	"	555	13	—	—	—	"	—	—	—	
52	"	8:21AM	TAKE-OFF 6 LOADED UNITS	—	—	—	—	"	—	"	0	—	582	12.5	—	—	—	"	—	—	—	
53	"	8:30AM	MOVIES IN FLIGHT	5	558 563 565 566 567 568 MISFIRE	141.3	11.0	"	—	—	—	—	—	—	—	—	—	—	—	—	—	
54	8-21-41	8:40AM	TAKE-OFF 6 DUMMY UNITS	—	—	—	—	1178	—	1+	0	—	605	—	—	—	—	1528	—	—	—	
55	"	8:44AM	"	—	—	—	—	"	—	"	"	—	600	—	—	—	—	"	—	—	—	
56	"	8:47AM	"	—	—	—	—	"	—	"	1	SW	580	13.2	—	—	—	"	—	—	—	
57	"	9:06AM	TAKE-OFF VS PORTERFIELD MOVIES	6	552 555 553 556 554 557	167.4	10.7	"	—	2	"	"	310	—	—	—	—	"	—	—	—	
58	8-21-41	9:45AM	YAW ON TAKE-OFF 3 UNITS ON RIGHT SIDE	3	561 568 562	84.6	10.9	1178	—	2	—	SSW	—	—	—	—	—	1528	—	—	—	
59	8-23-41	7:22AM	TAKE-OFF, NO PROP. 12 JET UNITS	12	569 571 570 572 573 587 574 588 589 591 590 593	335.8	11.4	"	—	—	2	NW	—	—	—	—	—	"	—	—	—	ATTEMPT TO TAKE-OFF WITH JET ALONE. 6 JET UNITS FIRED AT START AND SECOND 6 ABOUT 7 SECONDS LATER. TAKE-OFF SPEED NOT REACHED.
60	8-23-41	8:15AM	TAKE-OFF, NO PROP. 12 UNITS, INITIAL ROLL	11	575 577 576 578 579 581 580 582 583 585 584 586 MF	306.5	11.4	1178	—	—	3	E CROSS WIND	TOOK OFF	9.5 TO GET IN AIR 18 TAKE-OFF + FLIGHT		—	—	1528	—	—	—	ERCOUPE TOWED TO ABOUT 30 MPH BY TRUCK. ALL 12 UNITS FIRED ABOUT SAME TIME. NO PROP. ERCOUPE TOOK OFF AND CLIMBED TO ABOUT 20 FT. PLANE LEFT GROUND AND SETTLED BEFORE FINALLY TAKING-OFF. CONTROL WITH JETS ON GOOD. WHEN JETS STOPPED HAD LARGE DIVING MOMENT.
61	8-23-41	8:55AM	TAKE-OFF WITH 6 LOADED UNITS	—	—	—	—	1178+	—	—	0	—	600	13.5	—	—	—	1528	—	—	—	BRACKETS FOR ADDITIONAL 6 UNITS OF PREVIOUS TEST LEFT ON ADDING EXTRA DRAG AND WEIGHT.
62	"	9:07AM	TAKE-OFF WITH 6 JET UNITS	6	594 597 595 598 596 599	163.8	11.4	1178+	—	—	"	—	380	7	—	—	—	"	—	—	—	REMARKS SAME AS FOR TEST 61.

REEL – C

153

A.T.I.

6558

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AUTHOR(S): Malina, F. J.; Parsons, J. W.

ORIGINATING AGENCY: California Institute of Technology, Pasadena, Calif.

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